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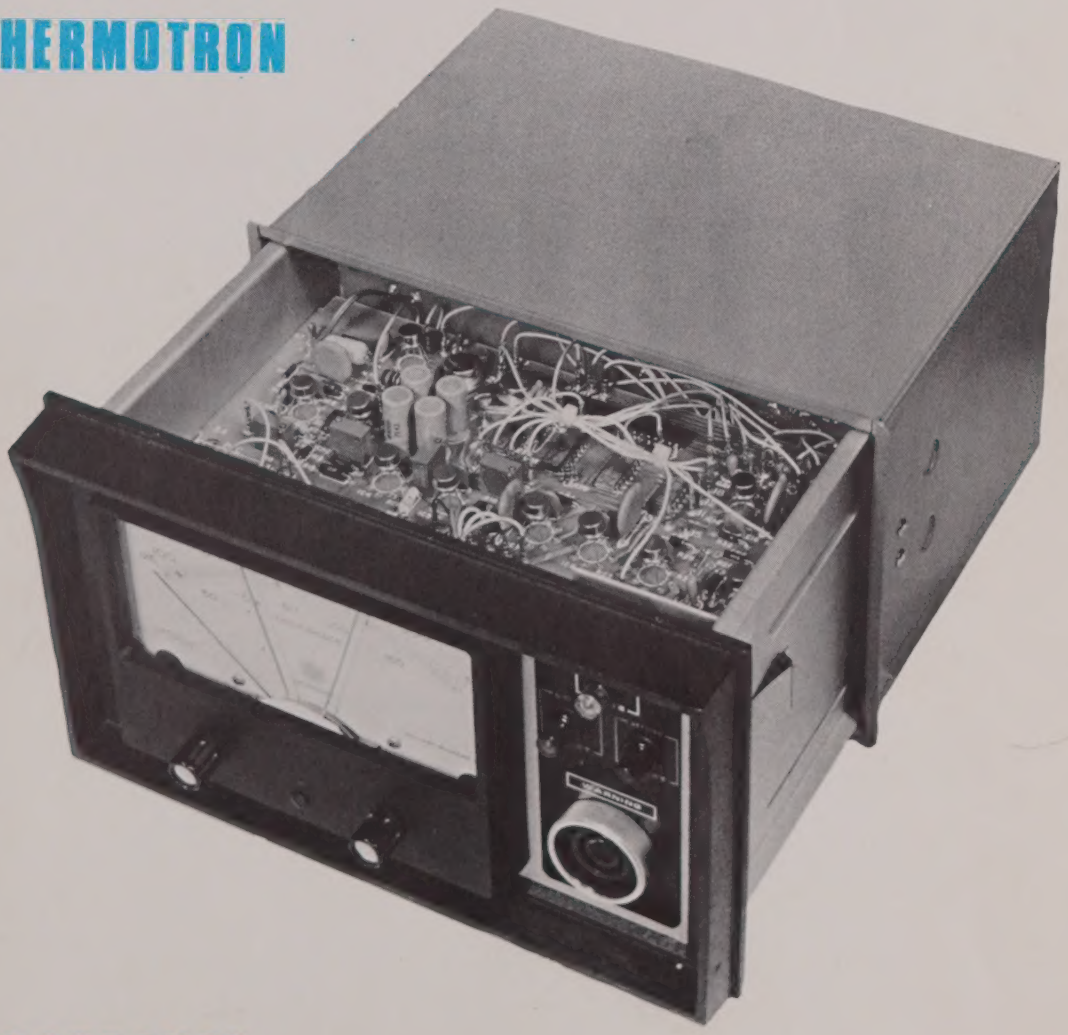
PRODUCTSAVER USER'S MANUAL

THERMOTRON



PRODUCTSAVER MODEL 012001, etc.

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PRODUCTSAVER USER'S MANUAL

INTRODUCTION

Productsaver Model 012001 is a complete temperature alarm system packaged in a single unit. A fully electronic device, the Productsaver is designed as a back up instrument for industrial applications where product quality can be jeopardized by out of tolerance temperature conditions.

Model 012001 is functionally similar to its predecessor, Model 1992, but includes several new innovations and offers improved overall performance. Except for its three output relays, the circuitry of the newer unit is fully solid-state, making widespread use of monolithic integrated circuit devices. Relays are retained at the output to provide the user with easily applied contacts for remote switching.

The newer package has also been provided with several new features which facilitate installation, calibration and maintenance. In addition, the newer unit provides the user with several functional options and variations, which may be implemented simply by changing certain plug-in connections within the unit.

OPERATION

The Productsaver is a bidirectional alarm system, which monitors temperature with respect to *both* a high and low limit setting. These two limits are independently adjustable over the full measuring range of the instrument.

A six-inch analog meter provides continuous temperature indication, and is also used as the means of establishing the high and low limit settings. The indicator is designed in such a manner that during normal operation the temperature indicating needle will fall between the two limit needles, and the proximity of the temperature to either limit can be observed at a glance, without actually reading the scale. Whenever the temperature varies outside of the zone established by the two limit pointers, audible, visual and electrical alarms will be generated.

The Productsaver is equipped with three alarm channels . . .

* High Limit
* Low Limit
* Hi/Lo Limit

Each of these channels has its own color-coded alarm light and output contact. The Hi/Lo Limit channel also provides an audible warning signal whenever it is activated by out of tolerance conditions.

The High Limit and Low Limit channels operate with respect to the high and low limit pointers within the temperature indicator. The Hi/Lo Limit channel operates with respect to both limit pointers.

Whenever the temperature indication strays outside of the zone established by the limit pointers, either the High Limit or Low Limit channel will be activated, depending upon the direction of the error. These channels provide the user with a warning light and a contact closure. The High Limit channel illuminates a red warning signal, while the Low Limit channel provides a green warning signal. The High Limit output contact may be used to deenergise heating equipment, while the Low Limit contact may be used to deactivate cooling systems.

Whenever either the high or low limit is exceeded, the third Hi/Lo Limit channel will be activated. This channel provides a flashing amber warning light, plus a pulsating audible warning signal. Its output contact is typically used to activate a remote warning device, such as a lamp or horn, to signal a supervisory computer, or to shut down the entire process.

As supplied from the factory, the High Limit and Low Limit channels must be *reset manually* whenever they have been activated, and after the out of tolerance condition has been corrected. Each indicator light doubles as a pushbutton switch which provides the reset function. Manual reset is accomplished simply by pushing whichever indicator is illuminated. The Hi/Lo Limit channel is reset automatically with the High Limit and Low Limit channels. The yellow Hi/Lo Limit warning indicator also serves as a muting switch for the audible warning device, which may be silenced prior to the time that the alarms can be reset. The Hi/Lo Limit contact will be either open or closed, and will not 'pulse' as do its associated warning devices. When the audible warning signal is silenced, the yellow warning indicator also changes its mode of operation from 'flashing' to 'steady-on.'

The Productsaver also provides three other distinct functions . . .

* Power failure detection and warning
* Automatic restart
* Sensor break detection and warning

In the event that the thermocouple sensor becomes open-circuited due to burn out, breakage or bad connections, a special alarm and warning mode will occur. In this mode, the temperature indicator swings full downscale and is pinned against its downscale stop. Simultaneously, power is removed from the High Limit and Low Limit channels, deactivating their output relays (and any remote equipment powered through them), but without providing the customary red and green warning signals. At the same time the Hi/Lo Limit channel will be activated, providing its associated audible, visual and electrical warning signals. Hence, *whenever the sensor becomes defective* and Productsaver protection is lost, all remote equipment controlled through the Productsaver is stopped, and the 'yellow lite only' indication at the Productsaver serves to inform the user that the temperature sensor is faulty . . . a self-troubleshooting feature which is provided in order to minimize down time.

As provided from the factory, the Productsaver is wired for *automatic restart* operation. By means of this function, alarms will be generated upon start-up only if the temperature is not within limits. When power is applied, the Productsaver switches to a self-reset mode for fifteen seconds, after which time it reverts to its normal manual reset mode. This convenience feature eliminates 'nuisance trips' associated with power surges, momentary power failures or maintenance shut-downs. It is especially helpful in restarting processes which are heavily protected with a variety of alarm devices.

Where *power failure detection* is desired or when the self restart feature is not advisable in processes which must be started sequentially, the Productsaver can be configured for manual restart by the user. This 'Operational Option' is discussed more thoroughly below.

APPLICATIONS INFORMATION

PROTECTION AND UNCERTAINTY

The Productsaver is intended primarily as a temperature limiting device. When applied in such service, the expectation is that this device will help to assure against hazards or loss resulting from extreme temperature conditions.

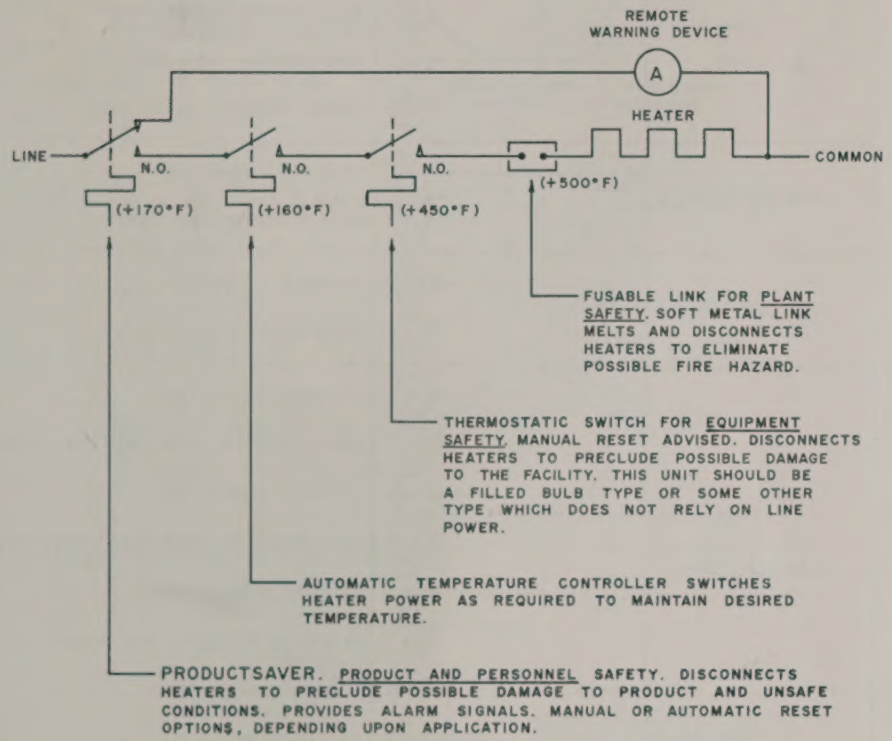
Both "Murphey's Laws" and the laws of probability indicate that "if it can happen, someday, somewhere, it will happen." Practical experience soon teaches all of us that this law is valid, and we soon learn to plan for the worst in order to avoid unpleasant surprises.

In spite of man's best efforts, *it is virtually impossible to produce a safety device which provides for "safety" with 100% reliability.* There is always some level of *uncertainty.* Any man-made device is subject to failure. *Failsafe* features allow for this reality by providing that, when such failures do occur, they will occur in a manner which is conducive to safety. For instance, when a limit switch is used, it should be mechanically returned to its "out of limits" position in the event of its failure. But the question of uncertainty still remains since it is still possible that the device will fail in some way which cannot be failsafed, such as sticking switches or welded contacts. In Productsaver applications, 'planning for the worst' is simply a matter of reducing its probablility of occurance. The first step is good design, good workmanship and quality materials. The second step is redundancy in that part of the system which is dedicated to safety. This simply means that if one safety device is good, two will be better. Naturally, the extent of redundancy allowed depends upon what happens if the safetys fail. Where the results could be catastrophic, an expensive system of safeguards could be a good investment, and reliance upon a single device would be foolhardy.

While it might sometimes seem 'overcautious' or 'overpessimistic' to simply duplicate safety devices in an electrical system, hierarchical safety systems usually make sense. When any safety device is employed, the usual intent is insurance against loss. In a hierarchical safety system, the insurance increases as the potential loss becomes more serious.

PROCESS SAFETY HIERARCHY:

UNCERTAINTY DIMINISHES AS LOSS POTENTIAL INCREASES


REMOTE
WARNING DEVICE
A
HEATER
LINE
N.O.
N.O.
N.O.
COMMON
(+170°F)
(+160°F)
(+450°F)
(+500°F)
FUSABLE LINK FOR PLANT SAFETY. SOFT METAL LINK MELTS AND DISCONNECTS HEATERS TO ELIMINATE POSSIBLE FIRE HAZARD.
THERMOSTATIC SWITCH FOR EQUIPMENT SAFETY. MANUAL RESET ADVISED. DISCONNECTS HEATERS TO PRECLUDE POSSIBLE DAMAGE TO THE FACILITY. THIS UNIT SHOULD BE A FILLED BULB TYPE OR SOME OTHER TYPE WHICH DOES NOT RELY ON LINE POWER.
AUTOMATIC TEMPERATURE CONTROLLER SWITCHES HEATER POWER AS REQUIRED TO MAINTAIN DESIRED TEMPERATURE.
PRODUCTSAVER. PRODUCT AND PERSONNEL SAFETY. DISCONNECTS HEATERS TO PRECLUDE POSSIBLE DAMAGE TO PRODUCT AND UNSAFE CONDITIONS. PROVIDES ALARM SIGNALS. MANUAL OR AUTOMATIC RESET OPTIONS, DEPENDING UPON APPLICATION.

Such a system is illustrated here, as a hypothetical industrial process which is normally operated at a temperature of +160°F. The general operation of this system is explained in the illustration. Each safety device is set to operate at a progressively higher temperature in order to protect against events which are progressively more serious. The scheme is:

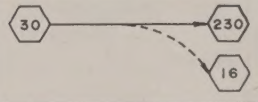
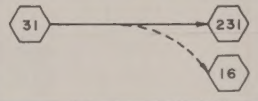
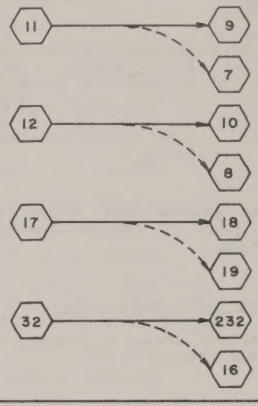
	Adversity	*Cause*
(Adverse)	Lost time,	Controller failed
(Bad)	and Lost Grade A product,	Controller and Productsaver failed
(Worse)	and Lost production facility,	Controller, Productsaver and limit switch failed
(Worst)	and Plant fire.	Controller, Productsaver, limit switch and fusable links all failed.

From this it is evident that as the adversity becomes progressively more serious, the probability of its ever happening becomes progressively less.

The third step in 'planning for the worst' is to institute a reasonable program of *preventive maintenance.* At the least, such a program includes performance checks on all operative devices, especially redundant safety devices. Since in normal operations these devices may never be called upon to perform their intended function, a periodic check is the only way to assure that they have not already failed in a way which cannot avert a catastrophe. The program should also include the following:

- *general cleanliness and order, especially within electrical compartments and around exposed contacts and electrical connections.
- *inspection for "hot spots" involving electrical wiring and contacts.
- *inspection of electrical insulation.
- *inspection of electrical contacts and connections for tightness, loose strands of wire, broken strands, etc.

OPERATIONAL OPTIONS

CIRCUITS AFFECTED	OPTIONAL CONNECTIONS	OPTIONAL OPERATIONS
ALL LIMITS		AUTO RESTART – MANUAL RESET AUTO RESTART – AUTO RESET MANUAL RESTART – MANUAL RESET
HIGH LIMIT ONLY		STANDARD CONNECTION AUTO RESTART – AUTO RESET
LOW LIMIT ONLY		STANDARD CONNECTION AUTO RESTART – AUTO RESET
HI/LO LIMIT ONLY		STANDARD CONNECTION AUTO RESET FOR HIGH LIMIT CONDITIONS STANDARD CONNECTION AUTO RESET FOR LOW LIMIT CONDITIONS STANDARD CONNECTION K3 PULSES AT LIMITS (FOR REMOTE ALARMS) STANDARD CONNECTION NO AUDIBLE ALARM

KEY: ⬡ PIN CONNECTOR NUMBER
—— STANDARD CONNECTION
– – – OPTIONAL CONNECTION

NOTE: TO UTILIZE OPTION, REMOVE CONDUCTOR FROM STANDARD CONNECTION AND PLACE ON REQUIRED OPTIONAL CONNECTION. WHEN THE STANDARD CONNECTION IS USED, THE LIMIT IN QUESTION WILL BE OPERATED ACCORDING TO THE "ALL LIMITS" CONNECTION.

OPERATIONAL VERSATILITY

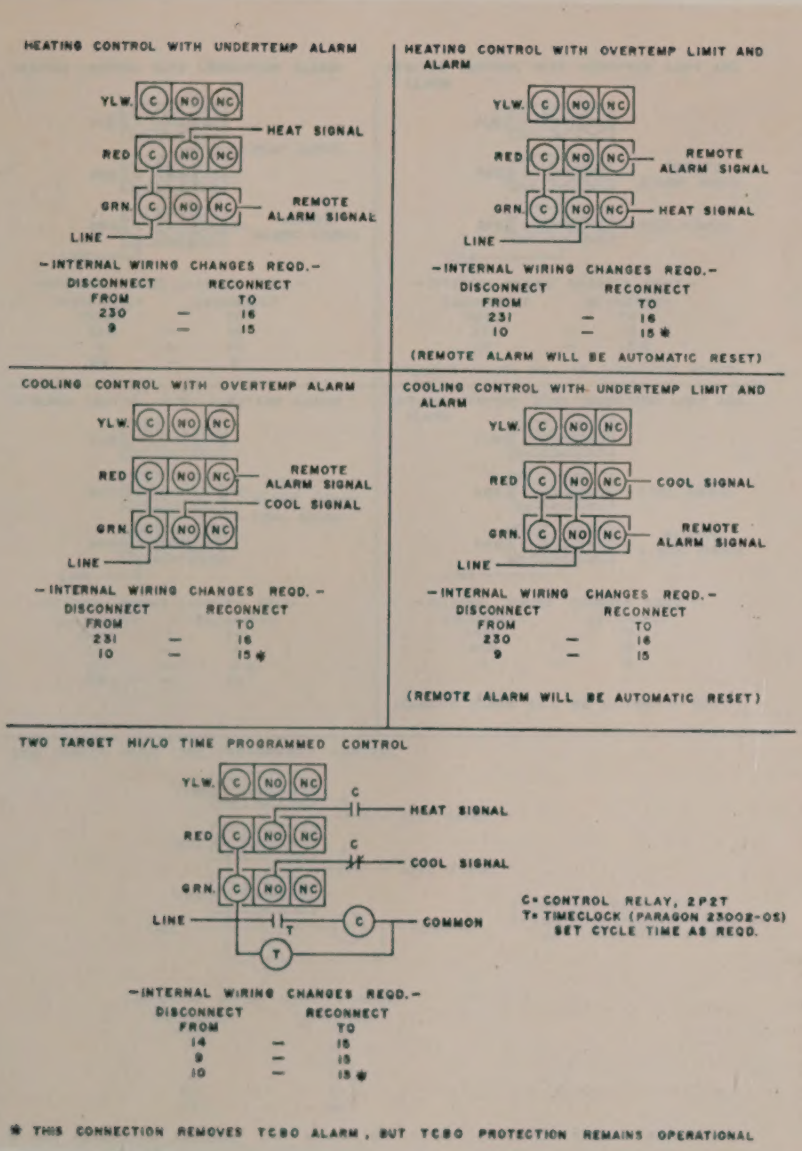
Productsaver Model 012001 has been designed to meet a wide variety of applications. As a part of this applications versatility, a means of changing certain operating characteristics of the unit has been provided.

Certain interconnections on the main circuit board of the unit have been 'softwired' using pins and wire receptacles. The standard interconnections can be changed quickly and easily by the user in order to provide the desired operational variation simply by unplugging the wire receptacle from one pin, and plugging it onto another, as indicated below.

The variations given here are those which will normally be of interest to the user. The connections shown as 'standard' are those which are made at the factory, and unless otherwise specified new units will be provided with these connections. Pin numbers are printed on the circuit boards next to the pins which they identify.

These variations may be applied either singly or in combination to achieve the desired operating characteristics. It should be remembered however that the operation of certain functions may be interrelated; for instance, if the High Limit and Low Limit channels are connected for automatic reset operation, then the Hi/Lo Limit channel will also be reset automatically.

The Productsaver can also be used as a back-up controller. Many control forms can be achieved simply by internal and external wiring variations. Several of these



control forms also provide automatic limit and alarm. Those control forms which are more popularly used are illustrated below.

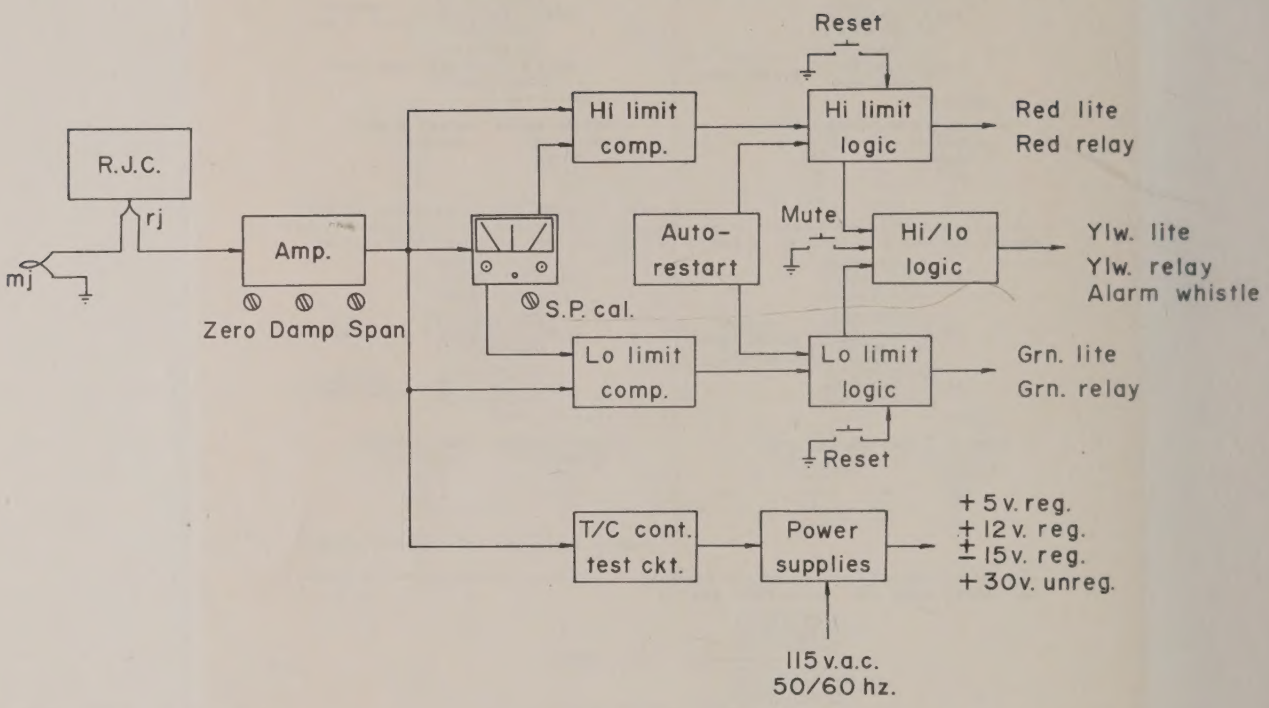
NOISE PROBLEMS

The Productsaver has been designed with a high level of "noise immunity." However, when the levels of ambient electrical interference are extremely high the unit can be affected. Such interference can produce the following symptoms either singly or in combination:

(1) nuisance alarms (false trips)
(2) unwanted self-reset operation
(3) chattering relay operation
(4) unstable but residual temperature measuring errors
(5) wavering of the temperature indicating needle.

Such noise usually results from switching highly inductive loads, which produces arcing at the switch contacts. Such sources are fairly easily suppressed below levels which will not disturb the Productsaver, since 100% suppression is not usually required.

Since individual cases vary, it is impossible to recommend a catch-all method of noise suppression here. However Thermotron - ACS Customer Service will be happy to participate in the resolution of such problems should any occur.



470100 BLOCK DIAGRAM

CIRCUIT DESCRIPTION

The circuitry of the Productsaver is reduced to its simplest form in the block diagram.

The Productsaver is equipped with a fairly elaborate *power supply* section. This module consists of three independent dc voltage supplies, which provide five dc voltage levels, four of which are electronically stabilized.

A +30v unregulated supply is provided for the reference junction control circuit. A bilateral tracking power supply provides +15v and -15v levels used by all linear integrated devices. A +5v supply provides power for all digital integrated devices, while a +12v supply is used as the drive power for the indicator lamps, relays and audible annunciator.

Separate voltage supplies are incorporated as a means of reducing interaction between circuits, especially between the high gain 'front end' and the high load switching circuitry at the outputs. The stabilized supplies all provide excellent line and load regulation, plus current limiting. The one unstabilized supply is regulated and subjected to current limiting within the circuit that it serves.

So much special attention to the power supply is unusual in this class of instrumentation. It has been made possible in this case through the use of monolithic integrated voltage regulator devices, and does much to assure high reliability.

The Productsaver utilizes a thermocouple as its *temperature sensor.* The resulting 'reference junction' is controlled rather than electrically compensated.

The *reference junction control circuit* is a complete temperature control system in itself, having its own heater, sensor and temperature control circuit. A switching type temperature controller is used to hold the reference junction at a temperature of about +160°F, and the offset which develops in the measurement due to its emf is removed by means of the *zero adjustment* just ahead of the amplifier. This technique is very similar to the use of an ice bath, except for the temperature levels involved.

The emf developed by the measuring junction, with the reference junction emf removed, is applied to the input of a *dc amplifier circuit.* Low offset and drift result from the use of a precision integrated operational amplifier circuit in place of the familiar 'chopper-stabilized' approach. The dc approach eliminates modulating signals

and demodulating circuitry, and the frequency response of the high gain amplification stage can be reduced to a minimum for improved noise immunity.

In addition to the low frequency response, special circuitry is incorporated following the amplifier circuit to provide further noise rejection. A *'damping' adjustment* at this circuit allows the user to adjust the response time of the instrument.

The output of the amplifier circuitry is scaled to an analog of . . .

0 to 100% of span = 0 to +5vdc

. . . by means of non-interacting zero and *span adjustments*. This signal is applied to the temperature indicating meter, the high and low limit comparators and to a circuit which monitors for sensor failures.

The *sensor continuity test circuit* acts like an ohmmeter connected across the measuring and reference junctions. If the sensor should happen to become open-circuited (burn out, breakage or bad connections) this circuit will drive the temperature indicator needle against its downscale stop to indicate an 'unreasonable' condition, and simultaneously removes power from the High Limit and Low Limit channels. This deenergises the High Limit and Low Limit relays (and any remote equipment powered through them), but without providing the customary red and green warning signals.

At the same time the Hi/Low Limit channel will be activated, providing its associated audible, visual and electrical warning signals. Hence, safety is assured so far as remote equipment is concerned, and the unusual alarm mode provides the user with a specific 'faulty sensor' indication as a self-troubleshooting feature.

The *temperature indicating meter* has two manually adjustable pointers which are used to establish the high and low temperature limits, in addition to its indicating needle. These pointers also function as wipers of an integral potentiometer. As they are set to the desired temperature, using the same scale as that used for the actual temperature indication, their associated wiper contact picks off a voltage equal to the set point temperature in terms of the 0 to +5V analog. These two set point voltages are applied to the High Limit and Low Limit comparators. A *scaling potentiometer* connected in series with the meter potentiometer provides a means of calibrating these output voltages in order to zero the 'trip points.'

The *limit comparators* analyze the amplifier output voltage with respect to the two set point voltages. The output of these switching circuits will be either high or low, depending upon the magnitude of the measured signal with respect to the individual set point signals. Switching occurs as the measured value crosses the set point value. These circuits have very high gain, and for precise switching no 'extra' hysteresis has been provided.

The High Limit and Low Limit *logic circuits* control the operation of the associated indicator lights and relays. Inputs to these circuits are derived from the limit comparators, the automatic restart circuit, the sensor continuity test circuit and the reset switches. The logic circuits interpret these inputs and operate the lights and output relays accordingly.

The Hi/Lo logic circuit derives its inputs from the High Limit and Low Limit logic circuits and the mute switch. It controls the operation of its associated alarm light, audible warning device and output relay.

The logic circuitry in the Productsaver is based primarily upon NAND gates. Monolithic integrated DTL devices have been used in the interest of reliability and good noise immunity.

The *automatic restart circuit* consists primarily of a time delay switch which provides a reset signal to the High Limit and Low Limit logic circuits for a period of 10 to 20 seconds following the reapplication of line power. If the measured value is able to achieve a 'within limits' condition during this timing interval, start up alarms will be automatically reset.

When this circuit is wired for power failure detection instead of automatic restart operation, all three alarm channels will be activated upon start up. This is achieved by virtue of the inherent start up sequencing of the Productsaver circuitry itself.

SPECIFICATIONS

Productsaver
Model 021001

Parameter	MIN	TYP	MAX	Units
Range [1]	-125		+375	°F
Measuring Accuracy[2]	1.0	0.5		%
Alarm Accuracy[2]	0.5	0.25		%
Measuring Resolution (scale readability)	0.2			%
Set Point Resolution	0.5			%
Temperature Coefficient of Measuring and Alarm Accuracy (drift with ambient temperature)		0.025	0.050	%/°F
Operating Temperature Range	0		+55	°C
Source Resistance[3] (thermocouple ohms)			100	ohms
Span Shift with Source Resistance (t/c ohms)		0.076		%/ohm
Power Requirements				
-Voltage	90	115	130	vac
-Current		75	200	mA ac
-Frequency	50		60	Hz

(1) Equivalent centigrade scale included on indicator
(2) Referred to absolute millivolts applied to input
(3) Uses ISA Type T (copper - constantan) thermocouple

INSTALLATION AND WIRING

New units should be inspected prior to installation. The outside of the unit should evidence no abuse during shipping and handling. Inspect the front and back panels for loose or damaged parts, missing fasteners, etc.

Remove the two shipping screws from the back of the case, and slide the chassis out through the front of the case until it stops. The inside of the unit should be inspected for loose wires, loose parts and any other signs of internal discrepancies.

For safety during subsequent handling, the two shipping screws should be replaced before proceeding further.

The Productsaver is designed for panel mounted service. Input requirements consist of 115 vac 50/60 Hz line power, a ground connection and a thermocouple. In selecting a mounting location, the following should be considered:

- -the front panel should be oriented in full view and within ear-shot of operator personnel.
- -a seven inch clearance is required behind the mounting panel.
- -the mounting location should be free of shock, vibration and electrically radiated noise.
- -access to the power source and ground.
- -remote control-wiring requirements, if any.
- -100 ohm max thermocouple lead resistance.

In order to mount the Productsaver, provide a rectangular hole at the desired location measuring

5 1/4" high x 9 1/16" wide

Remove the two kncok-out slugs from both sides of the case at this time. To do this, remove the two shipping screws from the back of the unit, and slide the chassis out thru the front of the case until it stops. Push the slugs into the case with a screwdriver and, working thru the back of the case, wiggle them loose using long nose pliers. When finished, close the unit and replace the shipping screws.

Push the Productsaver case thru the mounting hole from the front of the panel. Two special mounting brackets are shipped with each unit. The two holes on each side of the case accomodate the two ears on these brackets. Install the brackets from behind the mounting panel such that the screws in the brackets tighten against the back side of the panel. Tighten these screws *only* until snug, then tighten their jamb nuts securely.

Three relays and three relay retainer clips are shipped in a separate package with each unit. Install these three relays in the sockets provided at the back of the Productsaver. Be sure to use the retainer clips in order to assure proper mounting in the presence of vibration.

—NOTE—

All wiring connected to the rear of the unit should include enough slack to allow withdrawal of the unit from the front of its case for maintenance and calibration purposes.

The terminals at the rear of the Productsaver will accomodate wires up to size AWG No. 16 without soldering, lugging or staking.

The actual current drain of the Productsaver will not, in normal operation, exceed 250 mA ac. A five amp fuse is recommended, and should be installed in the hot side of the line. A remote ON-OFF switch is usually not recommended, except as a concealed control to facilitate maintenance if shut down of the system can not be tolerated in case of Productsaver failure.

A power source should be selected which is free of electrical disturbances which may be transmitted into the Productsaver. In general, power sources which are used to drive motors, solenoid valves and power contactors will prove troublesome to normal operation of the unit. Noise transmitted from these sources can cause erroneous temperature indications and nuisance trips. If a separate line is not available, it may become necessary to apply noise supression techniques to certain other devices which share the power line.

The power terminals are marked:

L= line connection ('hot' side)
N= neutral or common connection
E= earth or ground connection

The ground connection is important in terms of noise immunity as well as safety. This terminal should be connected to a good ground rod or 'water pipe' ground using AWG No. 16 wire. If the distance to the groundconnection exceeds ten feet, a heavier ground cable is advised.

When connecting the thermocouple, observe the color code at the input terminals so as to assure that the wire type and polarity are correct. The resistance of this lead must not exceed 100 ohms. Since the resistance of thermocouple wire varies directly with its length and inversely with wire size, light gauge wire can be used for short runs, while heavier gauge wire may be required for longer runs. Use only premium grade wire and, if necessary, refer to the standard resistance data for the type of wire used prior to running this line.

Since the thermocouple emf is a low level signal, this input is particularly vulnerable to transient electrical radiations. The thermocouple leadwire can act as an antenna which picks up such stray energy and couples it into the unit. Although the circuitry of the Productsaver includes several features designed to cope with this problem exclusively, the fact remains that *noise suppression techniques are most effective when applied at the source of the interfering signals, rather than at the point of interference.*

Hence, this lead should not be routed in close proximity to power lines or thru localities which are known to be noisy. In certain cases shielded extension wire or the use of grounded conduit for this lead may be indicated. For the same reason, it is usually advisable to keep this lead as short as possible.

Wiring to the output contacts of the Productsaver will depend upon the nature of each application. These contacts are rated

5A @ 28vdc/4A @ 115vac

They are marked

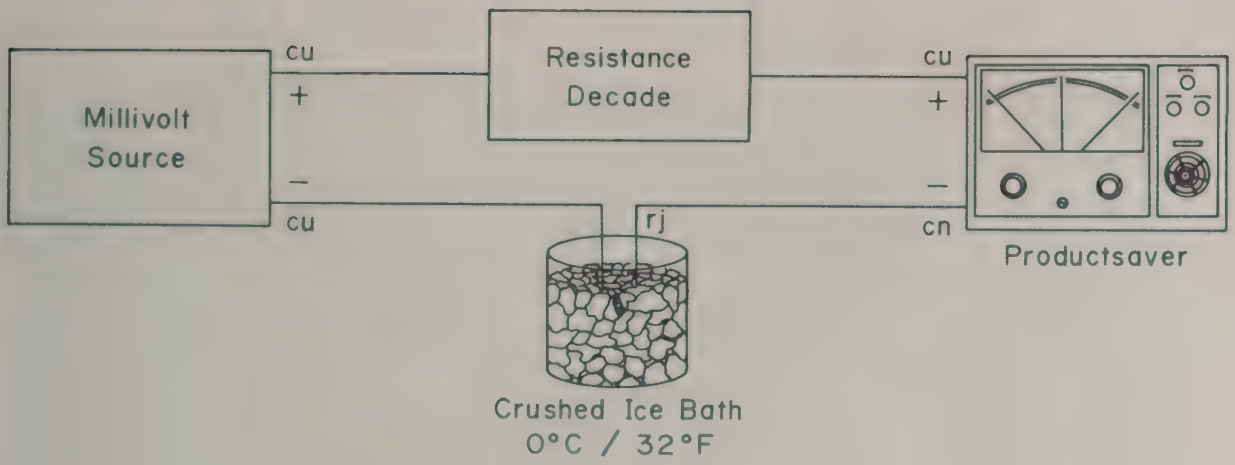
N. O. = normally open

N. C. = normally closed

C. = common

These legends apply to the relay itself, in the *deenergised* state. The relays are energised during normal operation and will be *deenergised when an alarm occurs* or when power is removed from the unit.

To relay control power to a function that should be ON during normal operation and OFF if an alarm condition occurs, connect the power source to 'C' and the function to 'N. O.'. To operate a remote function when an alarm occurs, such as a remote warning bell, connect power to 'C' and the remote function to 'N. C.' . The color code used at the output terminals corresponds with the indicator lights on the front of the unit. Each relay will be switched in conjunction with, and for the same reason as, its associated indicator light. For further information refer to sections II and III, above.



470103 CONNECTION DIAGRAM FOR PRODUCTSAVER CALIBRATION

CALIBRATION

The Productsaver circuitry includes a total of six trimmer potentiometers which are used to adjust

+15vdc level	electrical zero
-15vdc level	electrical span
set pointers calib	electrical damping

A mechanical zero adjustment is also provided on the temperature indicating meter.

All of these adjustments can be accomplished in the field. A voltmeter, an ohmmeter and a millivolt source (portable potentiometer, etc.) are normally required, depending upon the procedures used. The following procedures are recommended.

–WARNING–

In this procedure, work must be done with power applied to the unit. A potential of 115vac 50/60 Hz. exists at various points on the power supply and terminal circuit board assemblies. EXERCISE DUE CAUTION TO AVOID THE HAZARD OF ELECTRIC SHOCK.

–CAUTION–

Inadvertantly causing short circuits in the Productsaver circuitry can result in permanent component failures usually thru the destruction of semiconductor junctions, Use care in placing test probes, clip leads, screwdriver tips, etc.

–SET UP–

Remote equipment may be connected thru the Productsaver output contacts. Prior to proceeding, assure that such equipment, if any, will not be adversely affected by the calibration procedure.

Disconnect the measuring thermocouple from the terminals at the back of the unit. Connect these terminals to the millivolt source using the type of thermocouple extension wire indicated at the terminals. *Note that a 'second junction' is formed at the millivolt source.* If the source does not include 'automatic reference junctioncompensation,' immerse this junction in a bath of melting crushed ice. Set the millivolt source to provide an output which drives the Productsaver indicator pointer to about 50% of span.

THERMOCOUPLE & DUPLEX EXTENSION WIRE RESISTANCE

OHMS / DOUBLE FOOT AT 70°F

SIZE	TYPE J	TYPE T
2	.005	——
6	.014	——
8	.022	——
11	.043	——
12	.054	.047
14	.089	.074
16	.137	.117
18	.221	.190
20	.350	.297
22	.550	.475
24	.870	.754
28	2.261	1.920
30	3.568	3.040

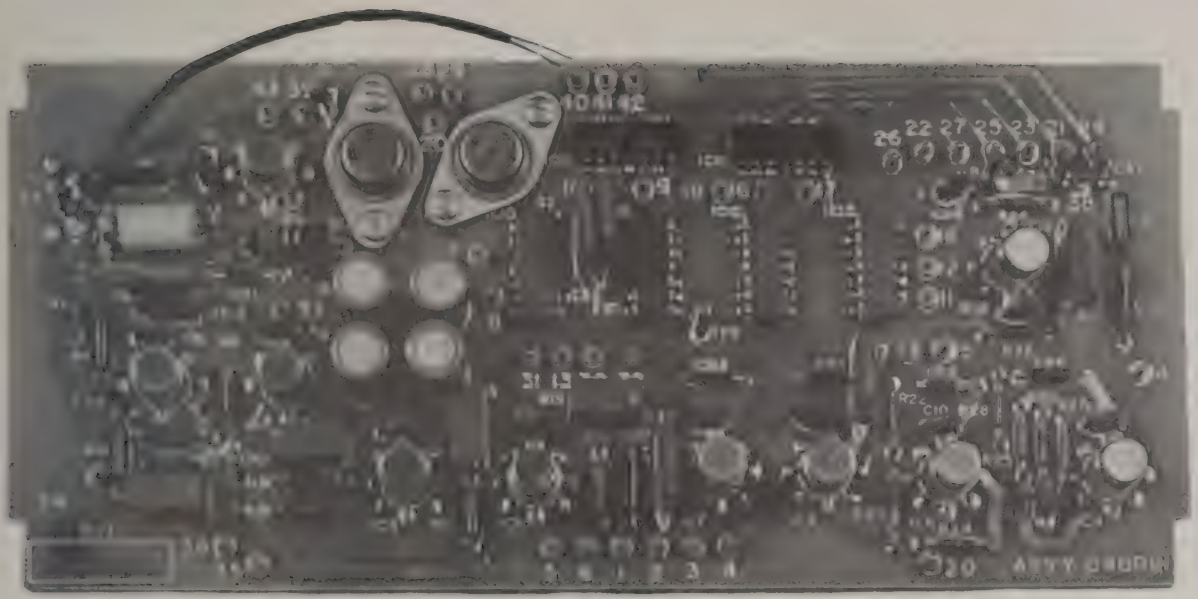
470102 RESISTANCE TABLE

1. Remove the two shipping screws at the rear of the unit. Pull the chassis out from the front of the case until it stops, while assuring that all wiring connected to the terminal board properly clears the back edges of the case.
2. Connect the dc voltmeter (DVM preferred - set on 20vdc range) to the main circuit board.
   (-) lead to pin 35
   (+) lead to pin 33
3. Adjust R40 on the front L/H side of the power supply board for an indication of exactly +15.0vdc.
4. Move the
   (+) lead to pin 36
5. Adjust R42 (adjacent to R40) for an indication of exactly -15.0vdc.
6. Remove the voltmeter connections.
7. Locate R14 on the main circuit board. Unless there is a definite requirement for fast response, move R14 25-turns in the counterclockwise direction (produces fsr of approx ten seconds).
8. Remove power from the Productsaver.

—NOTE—

If this is not permissable or convenient, temporarily remove the receptacle from pin 1 on the main circuit board while performing the following allignment.

9. Adjust the mechanical zero adjustment on the face of the meter so that the indicating pointer rests exactly over the left end scale mark.



048001 MAIN PCB ASSY

–NOTE–

Use the mirrored scale whenever reading the meter, so as to avoid parallax. Position the eye in such a manner that the reflection of the needle is not visable.

10. If calibration seals are used, place one over the mechanical zero adjustment at this time, while assuring that the adjustment is not altered in the process.
11. Reapply power to the Productsaver.
12. Set the millivolt source to provide an output which corresponds to the temperature at the left end scale mark of the meter. If necessary, refer to the standard temperature vs emf' data for the thermocouple type used.
13. Locate R8 on the main circuit board. Adjust this potentiometer until the indicator pointer on the meter rests exactly over the left end scale mark.
14. Set the millivolt source to produce an output emf which corresponds to the temperature at the right end scale mark.
15. Locate R16 on the main circuit board. Adjust this potentiometer until the indicator pointer on the meter rests exactly over the right end scale mark.
16. Set the High Limit pointer such that its L/H edge rests exactly over the right end scale mark of the meter.
17. Connect the dc voltmeter (DVM preferred - set on 20vdc range) to the main circuit board

–COMPENSATING FOR Rs–

As can be seen on the Productsaver schematic diagram, the feedback path of amplifier IC2 consists of R12, R11 and the two thermocouple junctions rj and mj. The gain of the amplifier is

$$A_v = \frac{R12}{R11 + Rrj + Rmj}$$

The resistance of the thermocouple leadwire associated with mj is therefore significant in terms of the span calibration, by a factor of approximately ±.076%/±ohm. Increasing this external resistance (Rs) decreases the gain, causing the indication to read low, and visa versa. For instance, if the sensor resistance is 10 ohms, and the millivolt source used for calibration has an output resistance of .1 ohm, the calibration will be in error by a factor of about –0.76% at the full scale reading, by about –0.38% at the halfscale reading, etc.

For this reason the dc resistance of the sensor wiring should be reconciled when the span adjustment is performed.

Find the resistance of the sensor leadwire by direct measurement with an ohmmeter, or by referring to the standard resistance data for the type and size of the thermocouple wire used. Then find the output resistance of the millivolt source used for calibration purposes and the resistance of the thermocouple extension wire used to connect the test instrument to the Productsaver. Then correct the emf setting for step 15 using the relationship

$emf_2' = emf_2 - [.00076(Rmj - Rs)\ (emf_2 - emf_1)]$

Where:
emf_1 = emf setting of step 12
emf_2 = emf setting of step 14
emf_2' = corrected emf setting for step 15
Rmj = resistance of sensor leadwire
Rs = source resistance of test set up

Alternatively, if Rs is less than Rmj, a decade resistor may be used to match the resistance of the test circuit to that of the sensor.

(–) lead to pin 5 (BLK meter lead)
(+) lead to pin 3 (YLW/WHT meter lead)

18. Locate R19 on the main circuit board. Adjust this potentiometer to produce an indication of exactly +5.0vdc,
19. Set the Low Limit pointer to about 25% of span and the High Limit pointer to about 75% of span.
20. Temporarily move the receptable connected to pin 14 to pin 15 (may already be connected to 15).
21. Vary the millivolt source as required to move the indicator pointer past the limit pointers. The alarms should actuate as the indicator pointer passes the inside edge of either pointer. If not, trim the setting of R19 as to optomize the allignment.
22. Replace the receptacle from pin 15 to pin 14 if moved in step 20.
23. This completes the calibration procedure. Push the chassis back into the case until it smaps into place.
24. Replace the two shipping screws at the rear of the unit. For calibration security, a seal may be placed over one of these screws to prohibit access to the adjustments inside the unit. (If missing, these screws are 'type A- self tapping,, No. 6.)
25. Disconnect the millivolt source, and *reconnect the thermocouple sensor* to the terminals at the back of the unit, according to the polarity indicated at the terminals.

FUNCTIONAL ANALYSIS

The following paragraphs explain the operation of the Productsaver circuitry in detail, as an aid to maintenance personnel. Each section of the circuit is treated individually. Readers should refer to the schematic diagram when studying this text.

The Productsaver includes five circuits which convert ac power from the line (115v 50/60 Hz) to dc power for the rest of its circuitry. Four of these power supplies are regulated electronically such that their output voltage will remain relatively stable over a variety of input and load conditions. As with any such device, proper operation of the Productsaver depends upon proper power supply performance. Hence, the *power supplies* should always be suspect whenever any type of failure occurs.

Line power is brought into the Productsaver on pins 345, 346 & 347 of the terminal circuit board. These pins are jumpered to pins 145, 146 & 147 on the power supply circuit board. Capacitor C31 is used to drain noise currents from circuit ground to earth ground.

At the *bipolar 15vdc power supply*, transformer T1 reduces the 115 vac line power to 24vac. The center tapped secondary of T1 serves two rectifier circuits. Diodes CR10 and CR12 comprise the positive full wave rectifier, while diodes CR11 and CR13 serve as the negative full wave rectifier. The transformer is shielded to prevent transient voltages appearing on the line from being capacitively coupled into the supply. Capacitors C17 and C20 provide filtering of the unregulated rectifier outputs.

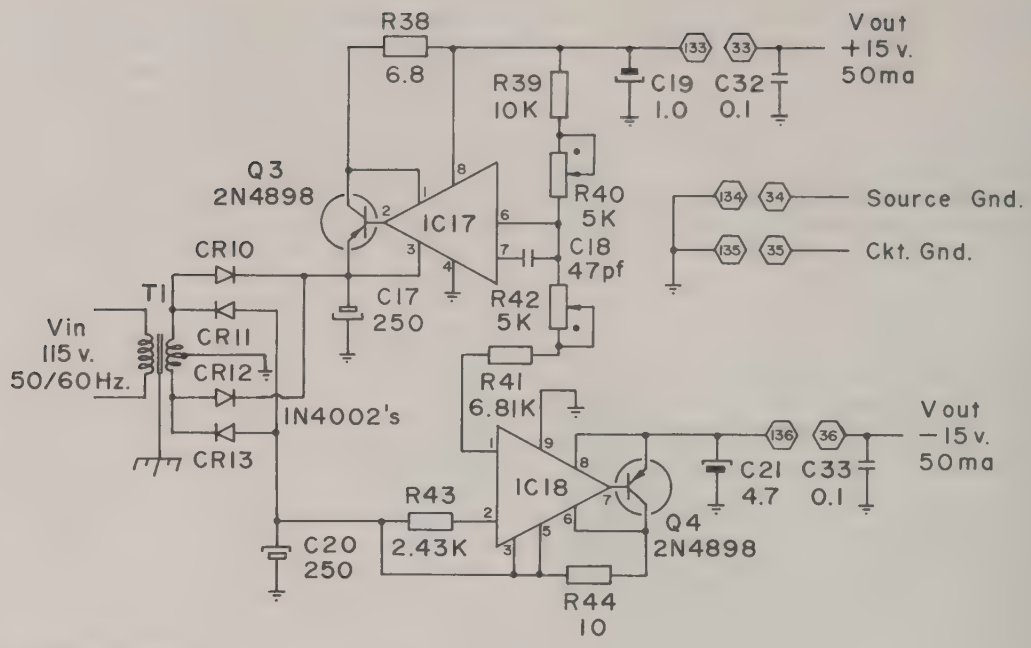
Since the 15vdc levels are used to provide power for bipolar intergrated circuits, it is important that these two supplies remain balanced with respect to each other. Tracking regulators are therefore used. This means that a variation at one output will result in an equal but opposite variation at the other output.

IC17 is an integrated positive voltage regulator, and IC18 is an intergrated negative voltage regulator. Power for IC17 is applied between pin 3 and pin 4, while power for IC18 is applied at pins 3 & 5, pin 9 being the ground connection. Pin 8 of either device is the regulated output terminal. Transistors Q3 and Q4 are booster transistors, which allow the integrated devices to control power levels which are several orders of magnitude higher than their own maximum power dissipation capabilities. These transistors regulate the load current such that the voltage drop across either load will be 15 volts. They, in turn, are controled by the booster output terminal of their associated I. C. by means of base current (pin 2 of IC17 and pin 7 of IC18).

The operation of these two regulator devices is as follows. IC17 has its own internally generated, temperature compensated reference voltage, which is typically 1.7vdc. It controls Q3 so as to establish and maintain a balancing potential of 1.7vdc at its feedback terminal, pin 6. The feedback voltage is dependant upon the output voltage; hence, any change in the output will be reflected at pin 6, and corrective action will be taken to return output to the proper value. Meanwhile, IC18 provides a constant current source between pins 1 and 2, which drives the series network R39, R40, R42, R41, the current source, and R43, with a current of approximately 1.0mA. It can now be seen that the voltage drop across R39 and R40 is constant, which means that pin 6 of IC17 will vary directly with the +15vdc output. If R40 is set for 3.3K, this voltage drop will be 13.3vdc and pin 6 will see a net 1.7vdc only when the output at pin 133 is exactly +15vdc.

The operation of the IC18 is somewhat different. When R43 is fixed at 2.43K, the output of this regulator depends upon the total resistance of R41 and R42, and the potential at the far end of R42 (pin 6 of IC17). Resistor R43 provides a reference voltage, being driven by the temperature compensated constant current source in IC18. The relationship between the voltage at pin 136 and the total R41+R42 resistance is about 2.0vdc/KΩ, but varies with the potential to which R42 is connected. It can be seen that if either this potential or the unregulated negative input voltage changes, the constant current circuit within IC18 will have to shift its operating point somewhat so as to maintain the 1.0mA level. When this happens, the output at pin 136 will be corrected accordingly by other circuitry within IC18.

From the above it can be seen that these two regulator circuits are interdependant. The output of the positive regulator depends, in part, upon the constant current level provided by the negative regulator. At the same time, the output of the negative regulator depends, in part, upon the reference voltage (i. e., the voltage at pin 6) of the positive regulator. As a hypothetical example, assume that the reference voltage of IC17 drifts up to 1.8vdc, this would cause the positive output at pin 133 to rise to +15.1 vdc, so that the potential at pin 6 of IC17 will balance at 1.8vdc. At the same time, the output of the minus supply



47086 ± 15v. POWER SUPPLY

at pin 136 will change to −15.1vdc because the voltage at pin 6 of IC17 has changed from 1.7vdc to 1.8vdc. Similarly, the operating point of the positive regulator will shift so as to accomodate any shift in the (constant current) operating point of the negative regulator. Hence, these are 'tracking regulators'.

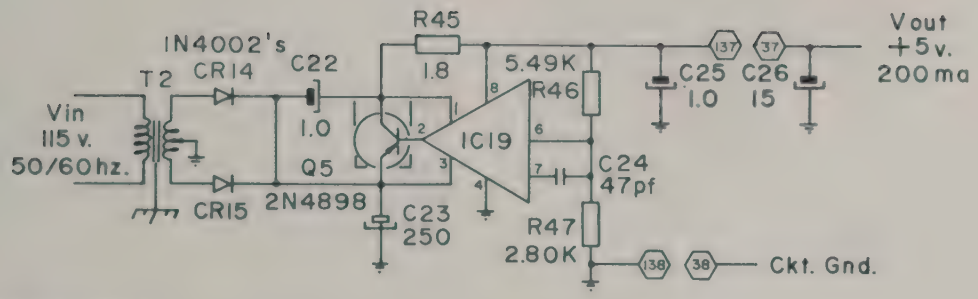
Current limiting is also provided for both outputs by the integrated devices. Pin 1 of IC17 and pin 6 of IC18 are current limit sense input terminals. The voltage drop across current limit resistors R38 and R44, respectively, initiates 'constant current' type limiting action when the load current reaches a level of about 50mA. This means, in other words, that the regulator will reduce its output voltage as required to keep the load current from exceeding 50mA.

Capacitor C18 is an external compensation capacitor for IC17 which is used to prevent high frequency oscillation within this high gain device. Tantalum capacitors C19 and C21 are used to minimize high frequency oscillation caused by a reaction between the junctions of the booster output transistor in the I. C.s and the booster transistor. Capacitors C32 and C33 are actually supply bypass capacitors located on the supply busses at IC7 and IC8, and prevent transients generated by these circuits from feeding back into the supply lines.

The *+5vdc supply* provides power for the digital circuitry, IC10 thru IC16. Line power is stepped down to 12vac by shielded transformer T2, and is converted to dc by full wave rectifier CR14 and CR15. C23 acts as a filter capacitor. Input power for IC19, an integrated positive voltage regulator is applied across pins 3 and 4. Load current is controlled by booster transistor Q5, which is driven by the I. C. from pin 2. The current limit sense voltage developed by the load current conducted thru current limit resistor R45, is introduced at pin 1 of IC19, the current limit sense input. Constant current limiting occurs at a load current of about 200mA.

IC19 generates its own temperature compensated reference voltage, typically 1.7vdc. Resistors R46 and R47 comprise a sampling network, the output of which is connected to the feedback terminal of the I. C., pin 6. In operation, the output voltage at pin 137 is controlled such that the feedback voltage at pin 6 equals the internally generated reference voltage. Illustrating that this condition will occur when the output voltage is +5vdc, is left as an exercise for the reader.

Compensation capacitor C24 prevents internal high frequency oscillation within the regulator. Capacitors C22 and C25 reduce high frequency oscillation caused by an interaction between the I. C. and the external booster transistor. Capacitor C26 is a decoupling capacitor which is actually located at IC15 and IC16 and is used to prevent transient voltages generated at these devices from affecting other devices which share this supply.



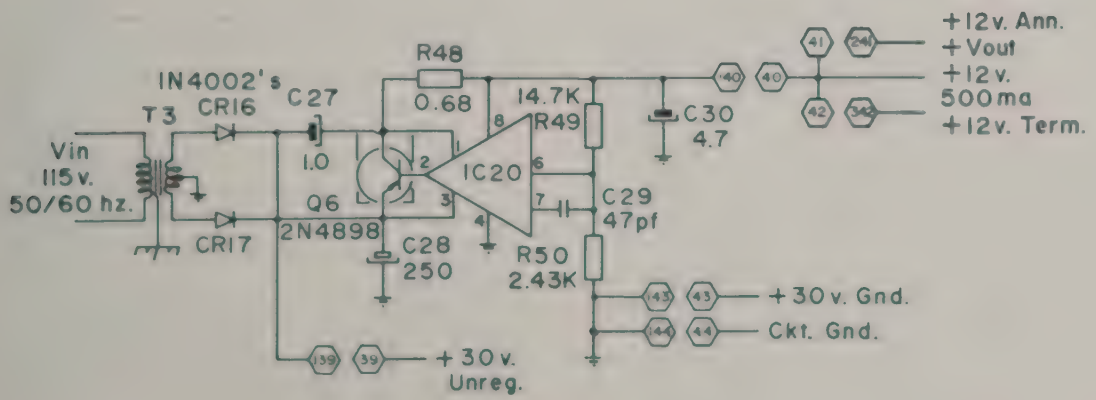
47087 +5v. POWER SUPPLY

The *+12vdc supply* provides power for the indicator lights, audible warning device and output relays. An auxiliary +30vdc unregulated output is also taken from this circuit to provide power for the reference junction control circuit, IC1. This supply is very similar to the +5vdc supply.

Line power is reduced to 30vac by shielded transformer T3, which is converted to +30vdc by full wave rectifier CR16 and CR17. C28 is the filter capacitor, and the +30 vdc unregulated output is provided at pin 139.

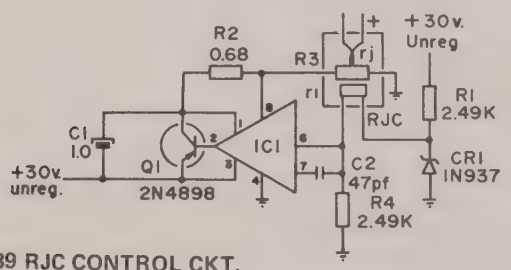
IC20 is a positive voltage regulator, and is powered at pin 3. Pin 2 drives booster transistor Q6. Pin 8 is the regulated output terminal, but the load current is conducted thru the current limit resistor R48, and back to the supply by Q6. The I x R drop occuring at R48 is applied to IC20 at the current limit sense input, pin 1, and constant current limiting occurs when the load current attempts to exceed 500mA. The R49-R50 network provides a feedback voltage to the regulator at feedback terminal, pin 6. This

As a troubleshooting note, the usual failure mode for these power supplies involves shorted booster transistors. This happens as a result of exceeding the maximum allowable junction temperature of the booster transistor which, in turn, may result from prolonged operation in a short circuit condition (current limit mode). In the +12vdc supply, for instance, Q6 may be called upon to sink 500mA at +30vdc, and thereby dissipate about 15 watts, if the load resistance drops to zero. High ambient temperatures may also precipitate such failures in normal operation, especially if heat sink efficiency is impaired by accumulations of dust or other contaminants. When the booster transistor fails in this manner, the associated I. C. is then called upon to handle the dissipation, and will also fail in most cases.



voltage is, in operation, balanced against an internally generated, temperature compensated reference of 1.7vdc. That this balance will occur when the output voltage at pin 140 is +12.0vdc is left as a reader's exercise. The compensation capacitor is C29; C27 and C30 are tantalum capacitors used to reduce the tendency towards oscillation which results from the combination of the IC and its booster transistor.

The *reference junction control circuit* is used to hold the reference junction, rj, at a fixed temperature level. The measuring junction, mj, is composed of two dissimilar wires, connected at one end. Because of a physical phenomenon known as 'the thermoelectric effect' junctions formed using certain types of dissimilar conductors generate an emf which is directly related to their temperature. This provides a very simple and accurate means of measuring temperature. On the other hand, the thermocouple has one serious disadvantage . . . the 'dissimilar' wire is dissimilar on both ends, and a second unwanted junction is always formed at the point where the thermocouple is connected to an emf-measuring instrument.



470089 RJC CONTROL CKT.

Needless to say, this second junction will also generate an emf. The emf of the second junction will be connected in series with, and opposes, that of the measuring junction. If the temperature and the thermoelectric characteristics of the second junction are known, it is possible to correct the erroneous emf measurement. To compensate the measurement in this manner one must know exactly what the instrument terminals are made of, and must also have some means of measuring the temperature of these terminals, which will not necessarily be the same as their ambient temperature. A very inconvenient method, and usually accompanied by a high level of uncertainty.

A better method involves forming the second junction intentionally, using the same materials used at the measuring junction, and immersing it in a bath of melting crushed ice. Since this junction is identical to the measuring junction, and since the temperature of the bath is fixed at +32°F (0°) by mother nature, the degree of uncertainty related to the emf measurement is significantly reduced. This is, in fact, a standard laboratory practice, and the second junction is more commonly referred to as the 'reference junction.' Also, the standard temperature vs. emf tables for various types of thermocouples indicate not what the actual mj emf is at a specified temperature, but rather what the net emf measurement will be when mj is at the specified temperature and rj is held at the 'ice point.'

In the case of the Productsaver it would be very inconvenient to maintain an ice bath for the reference junction. The next best approach is to change the reference temperature from +32°F to some more practical level, and to correct the emf measurement accordingly. The reference junction control circuit holds rj at a temperature of approximately +160°F.

It will be noticed that this circuit is similar in appearance to the +5vdc and +12vdc regulator circuits. In this circuit however, IC1 is used as a switching temperature controller, instead of a linear voltage regulator.

Thermistor r1, resistor R3 and rj are encapsulated in a common assembly. The resistor is used as a heater for the reference junction rj, while the thermistor is used as a temperature sensor. Current for heating R3 is provided by booster transistor Q1, which is controlled by IC1.

IC1 provides its own internal temperature compensated reference voltage, 1.7vdc. R1, CR1, r1 and R4 form a measuring circuit which provides an input to the temperature controller IC1. CR1 is a temperature compensated reference diode, and R1 is its series current limiting resistor. This combination provides a stable source of power for the measuring circuit, a potential of about 9.0vdc at the top of CR1.

The resistance of thermistor r1 varies inversely with temperature, low resistance at high temperature, and visa versa. Hence, when the temperature of the reference junction assembly increases; the resistance of r1 decreases, the current thru R4 increases, and the voltage drop (I x R) across R4 increases. Meanwhile, the operation of IC1 and its booster transistor Q1, depend upon the potential appearing at the feedback terminal of IC1, pin 6. If this potential is less than IC1's internal reference voltage, 1.7vdc, IC1 will turn on Q1, causing the reference junction assembly to be heated until the potential at pin 6 rises to 1.7vdc, whereupon IC1 switches off Q1.

The gain of this circuit is very high (about 30,000), so IC1 attempts to hold the temperature within a zone less than .001°F wide. However, the thermistor r1 has a time constant of about 2.0 seconds, which means that the indicated temperature (at pin 6) always lags the actual temperature (at rj). This hysteresis assures that IC1 can never operate in its linear range, and sustains operation in the switching mode. As the controller switches the heater current on and off, the temperature of the reference junction cycles above and below a mean value by about ±0.1°F.

Capacitor C2 is used to inhibit high frequency oscillation

tendencies within the IC which result from the fact that, because of its construction, the device is inherently an excellent high gain RF amplifier. Tantalum capacitor C1 is required to supress oscillations in the feedback loop involving the external booster transistor Q1 and the output transistor within the IC. Current limit resistor R2, in conjunction with the current limit circuitry in the IC, protects Q1 and IC1 against momentary short circuiting of the load current, pin 1 of IC1 being the current limit sense input. The +30vdc unregulated power provided from pin 139 at the +12vdc power supply is used by this circuit exclusively, providing power for IC1 at pin 3, for the heater at the emitter of Q1, and for the measuring circuit at R1.

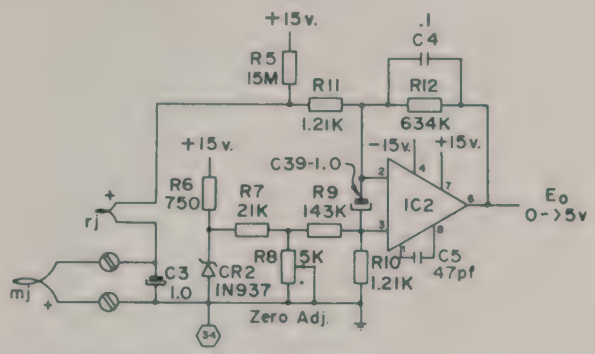
The emf produced by the measuring thermocouple is a low level signal. Its total variation over the temperature range of the Productsaver being typically not much greater than 10mV, depending upon the range and type of thermocouple specified for each particular unit. Hence, this signal is not directly useable, and requires amplification to power levels capable of driving the indicating meter, and as required for good sensitivity at the switching circuitry which operates the alarms. *The amplifier circuitry*, consisting of IC2, IC3, IC4, IC5 and their associated components, boosts the low level input signal to an output signal having a calibrated span of zero to +5.0vdc. In other words, as the temperature at the measuring thermocouple varies from the low end of the range to the high end of the range, the output of the amplifier will swing from ϕvdc to +5.0vdc. This analog is fundamental in the design of the Productsaver

ϕ to 100% span = ϕ to 5.0vdc

Thermocouple characteristics are not linear with respect to temperature however, so when we refer to temperature levels either in '% of span' or in terms of the five volt analog, it should be remembered that these expressions are directly analogous to the thermocouple emf, but not to its temperature. The degree of nonlinearity can be observed by inspecting the scale of the indicating meter.

IC2 is the *gain stage* of the amplifier, and must be designed with respect to the range and thermocouple type specified for the unit. At the time of this writing, units using type T (copper vs constantan) thermocouples and having a range of −125°F to +375°F predominate in the field, so the following discussion has been geared to this model (Model 012001) specifically. For the most part, this discussion will be applicable to all other units, with only minor zero and gain variations as indicated on the last page of this manual.

IC2 is a precision monolithic integrated operational amplifier circuit. The input offset voltage and current drift of this device have been reduced to the low typical values of 1.0μV/°C and 2.0pA/°C, respectively. Thru the application of this advanced device, performance approaching that of chopper stabilized amplifiers has been achieved without having to resort to that familiar, but unwieldy, solution to ambient temperature sensitivity.



470090 AMPLIFIER--GAIN STAGE

SHORT COURSE ON 'OP AMPS'

As can be seen on the Productsaver schematic diagram, the linear circuitry consists mainly of operational amplifiers in I. C. form. It is a fact of life today that, no matter how much a designer would like to 'be original', a given function can usually be achieved more readily and more economically by using these prefabricated building blocks. The results, in terms of performance and reliability, will generally be equal or better than anything that can be achieved with an original design using discrete components. It is predicted that during this decade I. C. sales will triple, while the sales volume of discrete components will be reduced by half.

At the time of this writing (late 1971) we find ourselves nearing the middle of this trend, which started in the early 1960's.

Progress and change presents demands for continuing education. Unfortunately, since hindsight is always better than foresight, it is difficult to predict what knowledge will be required in the future, and one often finds that he has a lot of catching up to do in order to 'stay current.'

The following is provided as a ready reference for those who have fallen behind, and may provide some basic answers in a moment of need. Only the rudaments are covered however, and the maintenance technician would do well to expand his knowledge of these devices further by reading any one of several good books on the subject.

As indicated in the schematic diagrams, the op amp is treated as a single replaceable part of the circuit. What happens inside of this device? At the maintenance level, the details of its inner workings will not usually be required in order to judge whether or not the device is functioning properly. As a general rule, the integrated op amp can be treated as a 'black box'

which

+ is an amplifier, a differential voltage amp
+ whose input impedance is infinite
+ whose output impedance is zero
+ whose open loop gain is infinite
+ whose power supply drain is insignificant

The pin connections shown on the schematic diagrams are, more or less, standard among all types of op amps.

As shown, these devices require bilateral power inputs (i. e., both a positive and a negative power supply). The negative supply is connected to pin 4, and the positive supply is connected to pin 7. In most applications the (+) and (–) power levels will be equal voltages, differing only in polarity. *Reversing the power connections to the device will usually result in its destruction.*

A small compensation capacitor is usually connected between pins 1 and 8 in order to stabilize the operation of the circuit. These devices are inherently excellent RF amplifiers, and in practical applications it is impossible to eliminate stray capacitances. Since the basic requirements for any self excited feedback oscillator are (1) an amplifier, (2) feedback in the proper phase and amplitude and (3) some sort of energy storage device to sustain oscillations and determine frequency, any practical op amp circuit is a potential oscillator. In the abscence of the compensation capacitor these circuits will almost certainly oscillate at a frequency of 1 - 5 megahertz whenever their output is not at the positive or negative limit (saturation).

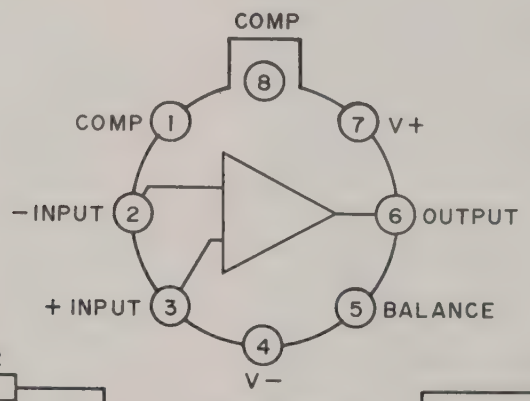
The op amp has two input terminals. Pin 2 is the *'inverting'* input, and pin 3 is the *'non-inverting'* input. Signals applied to pin 2 will be reproduced at the output with a greater amplitude and opposite phase. Signals applied to pin 3 will be reproduced as a magnified replica of the input (increased amplitude—same phase).

The output of the op amp is provided at pin 6. The output voltage can swing both positive and negative with respect to ground, and to within about 1.0 vdc of the supply potentials at saturation.

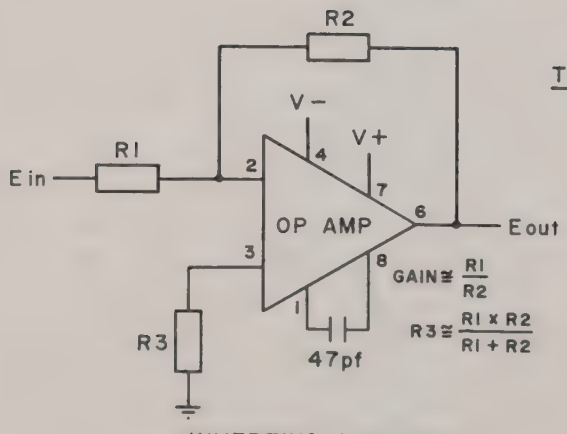
If the potentials at pin 2 and pin 3 are equal and of the same polarity, the output will be balanced at ϕvdc with respect to ground. In practical devices some small offset usually exists because of imperfections. This is known as the *'input offset voltage'* (the amount by which the inputs must be offset from perfect equality in order to bring the output to ϕvdc).

If the potential at pin 2 is greater (more positive) than that at pin 3, the output will be negative with respect to ground. Conversely, if the voltage at pin 3 is increased in the positive direction, the output will move in a positive direction.

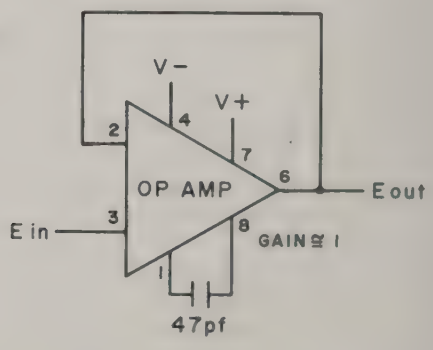
How much the output changes for a given input variation depends on the gain of the circuit. Unless limited by the addition of external networks, the open loop large signal voltage gain may be as high as 300,000. This can be reduced to any lesser value by



TOP VIEW



INVERTING AMPLIFIER



VOLTAGE FOLLOWER

external feedback networks, while a non-inverting voltage follower (gain = 1) can be achieved simply by connecting pin 2 to pin 6, using pin 3 as the input.

These devices generally have integral overload protection at both their input and output terminals. This means that shorting these terminals to either supply or ground will not usually not harm the device. If, however, these terminals are shorted to a potential exceeding the supply levels (e. g., if the power supplies have been turned off) destruction of the device is likely.

IC2 is operated as an inverting voltage amplifier whose gain is established by the feedback network consisting of R11 and R12

$$Av = R12/R11 = 524$$

With the measuring junction connected as shown, its emf . . . as felt at the input of the amplifier . . . will move in a negative direction as its temperature increases. This means that the output of the amplifier will move in a positive direction as the temperature increases.

The amplifier input connection is at the junction of R5 and R11. The emf appearing at this point is the net value produced by the series connection of mj and rj. Hence, the input emf can only be zero when the temperature of mj is the same as the temperature at rj, or about +160°F.

Recalling the basic analog used in the Productsaver circuitry, it is obvoius that the zero point of the amplifier will have to be shifted so that its output will be zero when mj is at a temperature corresponding to ϕ % of span. This is accomplished by means of the network consisting of R6, CR2, R7, R8 and R9, in conjunction with R10. R10 is selected so as to balance the impedances between either input terminal and ground, in the interest of maintaining good common mode rejection and to minimize the effects of input offset current.

CR2 is a temperature compensated reference diode, the operating point of which is established by series limiting resistor R6. This combination provides a stable potential of about 9.0vdc at its junction with R7. R7 and R8 form an adjustable voltage divider network. R9 serves to isolate the low impedance zero adjustment circuitry from the non-inverting input, and also functions as a series limiting resistor.

For the case in point, the ϕ % temperature is −125°F. When mj is at this temperature, the net emf applied to the amplifier input will be about +5.938mV. With pin 3 at ϕ vdc, this would produce an output of about

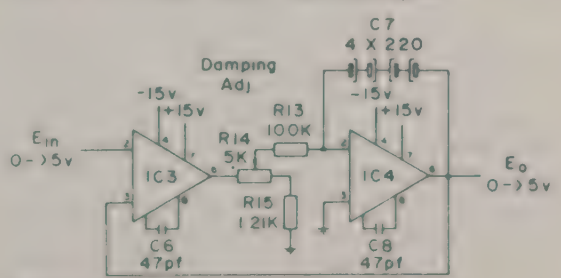
$$Eo = -Av \times Ei$$
$$= -524 \times 5.938mV$$
$$= -3.1vdc$$

In order to restore the output to zero with mj at −125°F, we can apply +5.938mV to the non-inverting terminal, pin 3. This is done by adjusting R8. The voltage at the top of R8 produces a current thru R10 and R9, and a voltage drop across R10 which is positive with respect to ground. Hence, R8 is adjusted until Iz x R10 = +5.938mV. The output of the amplifier stage will now be zero because its differential input is zero (both inputs at the same level).

Since the zero adjustment is actually referred to the indicating meter, it compensates for any offsets which may exist throughout the circuitry between mj and M1, in addition to shifting the actual zero point as required by the range specified for the unit.

C3 and C39 are provided for noise immunity. The input to the amplifier should be purely the dc emf's developed by rj and mj. Any electrical noise coupled into the unit on the sensor leadwire will appear as an ac input. C3 and C39 cross couple these ac inputs such that the *differential noise input* at IC2 is essentially zero, and no amplified noise will be produced at the output. C4 reduces the frequency response of the gain stage to further improve noise immunity; as the input frequency is increased, the impedance of the C4 R12 connection decreases, which decreases the gain of the circuit for ac noise components riding the dc input signal. C5 is the compensation capacitor for IC2. R5 is not actually part of the amplifier circuit and is discussed in connection with the sensor continuity monitor circuit, IC6.

The circuitry consisting of IC3 and IC4 is used to further reduce the frequency response of the amplifier section, in the interest of achieving a very high level of noise immunity. In simple terms, this circuit can be looked upon as a voltage follower having an extremely slow slew rate. Its input is pin 2 of IC3 and its output is pin 6 of IC4. Its output will always equal its input, so long as the input remains stable. But when the input changes, the output is moved to the new level very slowly. A voltage spike appearing at the input will not generally affect the output at all, since the transient input will have passed prior to the time that the output can begin to respond. On the other hand, if the input (which should be a pure dc level) has a residual ac component, the output will be essentially a dc level equal to the average value of the input signal.



470091 DAMPING CIRCUIT

IC3 acts as a voltage comparator, comparing the output signal from pin 6 of IC4 with the input signal provided from pin 6 of IC2. Its output switches between saturated extremes whenever its input changes significantly, switching to the positive saturation value (+14vdc) when pin 2 is negative with respect to pin 3, and visa versa.

IC4 can be described as a linear ramp generator whose output changes at the rate

$$\Delta Eo = -(Ein/RC)$$

where:

- ΔEo = output voltage rate of change (v/sec)
- Ein = voltage at the wiper of R14
- R = R13 (100K)
- C = C7 (55mfd)

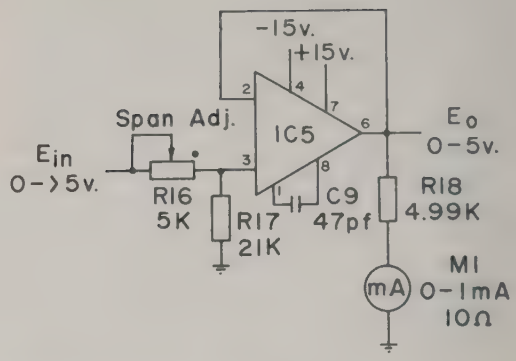
From the above the reader can calculate that the output slew rate is adjustable between the approximate limits of 0.5 volts/sec and 2.5 volts/sec. The formula also indicates ('–' sign) that when the input is negative, the output will be positive going, and visa versa. It can also be seen mathematically that the output rate of change is directly proportional to the input voltage, and therefore varies directly with the setting of R14 and the output of IC13.

By the terms of the above formula, if Ein = ϕv the output rate of change will be zero. This indicates that the IC4 circuit has a 'stop & hold' mode, which will occur when the output of IC3 is zero. Hence, the output of IC4 remains steady at a value equal to that at pin 6 of IC2, once it has reached this value, since at this point the voltages, applied to pins 2 & 3 of IC3 are equal and the output at pin 6 of IC3 will be ϕ v.

Capacitors C6 and C8 are the compensation capacitors for IC3 and IC4, respectively. The resistor R15 is selected so as to establish the minimum output rate of change at a practical level.

The output of IC4 is applied from pin 6 to the voltage divider network composed of potentiometer R16 and resistor R17. This network is used to scale the maximum output, which occurs when the temperature of the measuring junction is at a value equal to 100% of span, to exactly +5.0vdc. This is the *span adjustment* provision.

For the case in point (Model 012001) the net input emf appearing at the amplifier at 100% of span is approximately –11.768mV (zero factor included). With this input, the output of IC4 will be about +6.166vdc, so long as the gain of the amplification stage IC2 is 524. The gain of this stage, however, will diminish somewhat as the resistance of the sensor (mj) leadwire increases, since this resistance is connected in series with R11. The range of span adjustment provided by R16 will accomodate thermocouple resistances in excess of 100 ohms, permitting the use of over 100 feet of type T or type J wire.

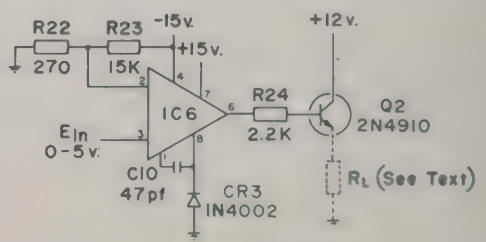


470092 VOLTAGE FOLLOWER

IC5 is a simple non-inverting voltage follower circuit. Its output at pin 6 is always equal to its input at pin 3. Its compensation capacitor is C9. This circuit has a very high input impedance, which means that its input current is insignificantly low so far as the span adjustment network and IC4 are concerned. At the same time its output impedance is very low, which means that it can provide considerable amounts of power to various load circuits with no degradation of output accuracy. Hence, this circuit is used to buffer the amplifier from the various load circuits, acting as the distribution center for the basic voltage analog of temperature.

One such load circuit includes the *indicating meter* M1 and resistor R18. That the meter reading will be ϕ% of span (lowest scale value) when pin 6 of IC5 is at zero volts obvious. By using the values given on the schematic diagram, the reader can calculate that the reading should be 100% of span (maximum scale value) when the voltage applied to the top of R18 is exactly +5.0vdc.

A second load circuit consists of IC6 and associated components, the *sensor continuity monitor circuit.* As can be seen on the schematic diagram, the ϕ – +5vdc analog signal is applied to pin 3 of IC6. R22 and R23 form a voltage divider which is connected totthe negative supply. The potential applied to pin 2 of IC6 is about –0.25vdc.



470093 SENSOR CONTINUITY MONITOR

The above observations indicate that the output of IC6, at pin 6, will be about +14vdc during all periods of normal operation. This potential is used to drive the base of pass transistor Q2. The base current of Q2 is limited to just over the saturation value by R24. This transistor relays +12 vdc power to the High Limit and Low Limit relays, and to the High Limit and Low Limit indicator lights, which are represented by R_L on the above diagram.

Referring back to R5, at the gain stage of the amplifier (IC2), it is evident that this resistor, rj and mj form a series circuit to ground, and that a current on the order of 1.0μA will flow thru this circuit. Though this may shift the zero point somewhat, any such offset is overcome during the zero adjustment procedure, and the presence of R5 therefore has no effect upon normal operation of the unit.

However, if continuity in the thermocouple circuit is disrupted (misconnected, broken or burned out sensor) the R5 current is diverted to a series circuit consisting of R5, R11 and R12, with pin 6 of IC2 being, effectively, a ground connection. The reader can calculate that at the instant such a fault occurs a potential of about +0.6v will appear at pin 2 of IC2. Since pin 3 of IC2 is at a potential of about +5.938mV, IC2 will move into negative saturation, with pin 6 driven to about −14.0vdc. This means that pin 6 of IC5 will also be driven to some deeply negative value, depending upon the span adjustment.

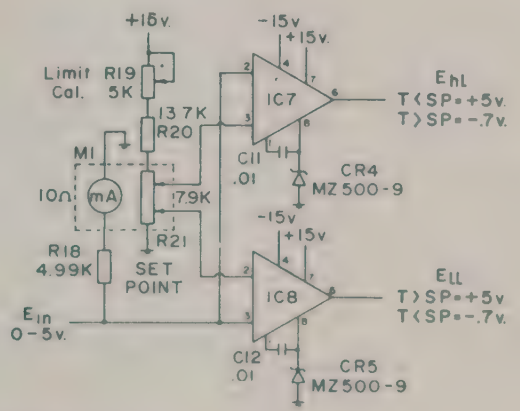
When this happens, pin 3 of IC6 will be driven negative with respect to pin 2, and since pin 3 is the non-inverting terminal the output of IC6 will go from +14.0vdc to about −0.7vdc. The output of IC6 is clamped at this low negative value by diode CR3, and is not permitted to go to the negative saturation value (about −14.0vdc). This, in turn, turns off transistor Q2, which removes power from the High Limit and Low Limit indicator lamps and relays, leaving the Hi/Lo Limit alarm system operating normally.

Since the output of the amplifier is negative, the indicating meter needle will be pinned against its downscale stop, providing the user with an 'unreasonable' indication. Also, since the analog has dropped lower than the lowest possible limit setting, the Low Limit alarm circuit will energise the Hi/Lo Limit circuit, which will provide its usual indications, but without a simultaneous High Limit or Low Limit indication. This particular combination of indications is provided as a self troubleshooting feature, and 'tells' the user that the sensor is faulty. In addition, any remote devices connected to the output relays of the Productsaver will be positively deenergised when such failures occur.

This circuit automatically resets itself when the trouble is corrected. Capacitor C10 is the compensation capacitor for IC6.

IC7 and IC8 are the *High Limit and Low Limit comparators,* respectively. The inputs to these circuits are the analog signal from pin 6 of IC5 and limit signals from potentiometer R21, which is built into the meter assembly. The outputs of these circuits are switched whenever the analog voltage crosses a limit value.

R19 and R20 are used to scale the voltage drop across R21 to match the analog voltage of ϕ − +5.0vdc. Potentiometer R21 has two wipers which are connected to the adjustable limit pointers within the meter assembly. One pointer is used to set the Low Limit value, while the other is used to set the High Limit value. These pointers are adjusted according to the temperature scale printed on the face of the meter, and their wipers simultaneously pick off a voltage appropriate to the temperature setting in terms of the basic ϕ − +5.0vdc analog.



470094 HIGH & LOW LIMIT COMP.

From the above it can be seen that whenever the indicating pointer of the meter is between the two limit pointers, pin 3 will be positive with respect to pin 2 at both IC7 and IC8. This means that the outputs of both comparator circuits (pin 6 of either) will be at a positive voltage . . . +5.1vdc due to the clamping diodes CR4 and CR5. The positive output levels must be clamped at +5.0vdc for compatability with the DTL logic I. C.'s which these comparators serve.

At IC7, if the analog input moves positive with respect to the limit input, the output will switch to about −0.7vdc, being held at this low negative value by CR4, whose forward voltage drop is about 0.7vdc. At IC8, the same will occur if the analog input moves negative with respect to the limit input. Capacitors C11 and C12 are the compensation capacitors for these circuits.

−POINT−

*Comparator output high = normal condition

*Comparator output low = limit condition

–DIGITAL INTEGRATED CIRCUITS–

Prior to continuing this discussion, a brief comment on digital logic circuits will be provided for those who are not familiar with these circuit elements.

The symbols labeled IC10, IC11, IC12, IC13, IC15 and IC16 represent digital logic circuits. Even if unfamiliar, these circuits are quite simple to understand, and are very easy to troubleshoot. This simplicity results from the fact that these circuits function only as switching devices, and that each input and output can have only two operational conditions high or low.

'high' = 1.4 to 5.0vdc
'low' = less than 1.4vdc

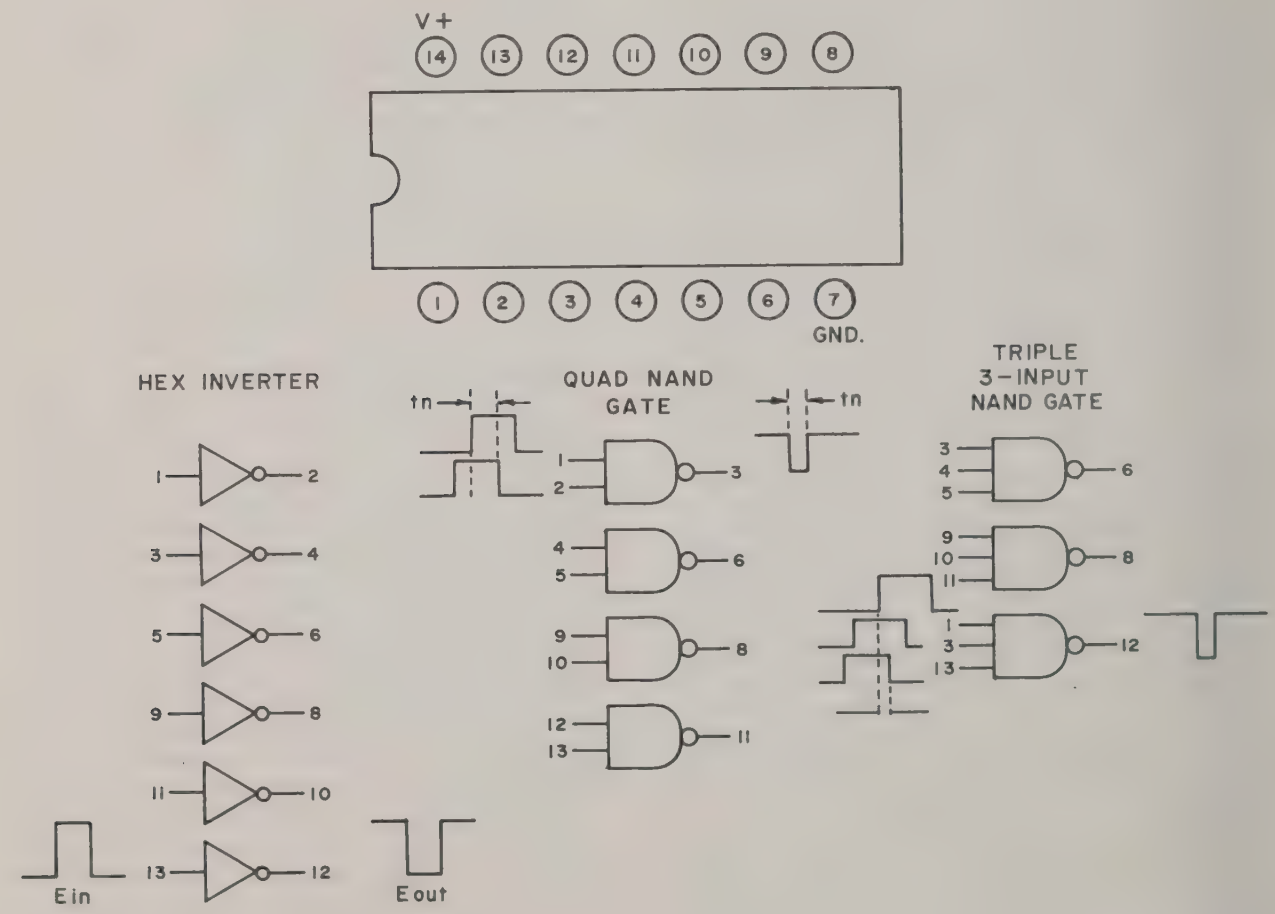
The small circle at the end of each symbol represents the output terminal of each device, while all other connections are inputs. A single integrated circuit may provide several circuit elements; for example four symbols are labeled '1/4 IC10', meaning that IC10 is actually a single package containing four logic circuits. Even though provided in the same package, these separate elements need have no operational relationship in the circuit, and operate independently. The only thing they have in common is a +5.0vdc power source and a ground connection at pins 14 and 7 of each package, respectively.

IC11 is a 'Hex Inverter,' meaning that it contains six inverter, or NOT circuits. The output of an inverter circuit is always the opposite of its input: the output is NOT the same as the input. Hence, if the input is high, the output will be low, and visa versa.

The rest of these devices are NAND circuits

IC10 & 12 = 'Quad Two-Input NAND'
IC13 = 'Triple Three-Input NAND'
IC15 & 16 = 'Quad Two-Input NAND'

A NAND circuit is achieved by combining an AND circuit with an inverter to produce the NOT AND, or 'NAND' function. In the AND circuit, the output will be high only when all inputs are high, and if the



output is then inverted, then the output of the combination will be low only when all inputs are high.

In dealing with these circuits in the Productsaver, one need only remember this:

THE OUTPUT WILL BE LOW, ONLY IF ALL OF THE INPUTS ARE HIGH. FOR ANY OTHER CONDITION THE OUTPUT WILL BE HIGH.

This applies to all of the elements, whether NOT or NAND, and without regard to the number of inputs. Sometimes the power NAND circuit causes confusion because of its output transistor. Consider IC15/4-5-6 for example. When both inputs are high, the output of the NAND section will be low, which turns off the driver transistor and the light I1. This seems right; inputs high - output low. However the voltage at the collector of the driver transistor raises to almost +12vdc when the transistor is cut off, and if a voltmeter is used to check the operation of the circuit it sometimes looks as though the logic is the same as an AND device.

Pin 6 of IC7 will be high (+5v) so long as the high limit has not been exceeded by the actual temperature. Hence, pin 10 of IC10 is high. For the moment we shall simply say that terminal 13, which is connected to IC11/11-10 and IC11/13-12, is low (ϕv). This means that pin 5 of IC10 is high. In normal operation pin 8 of IC10 will be low because of pre-established conditions. Hence, at IC10/4-5-6 we have

pin 4 : low
pin 5 : high = pin 6 : high

So, at IC10/9-10-8 we have

pin 9 : high
pin 10 : high = pin 8 : low

And, under these conditions

relay K1 : energised
Lamp I1 : off

When the high limit is exceeded, pin 10 of IC10 drops to low, causing the output at pin 8 of IC10 to swing high. Now, at IC10/4-5-6 we find

pin 4 : high
pin 5 : high = pin 6 : low

Reiterating, at IC10/9-10-8 we have

pin 9 : low
pin 10 : low = pin 8 : high

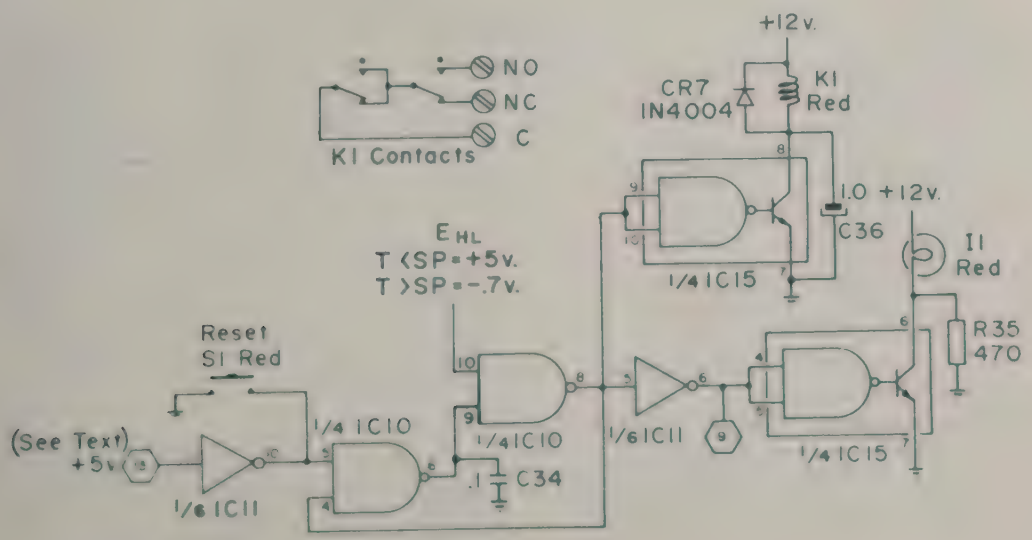
And, under these conditions

relay K1 : deenergised
Lamp I1 : on

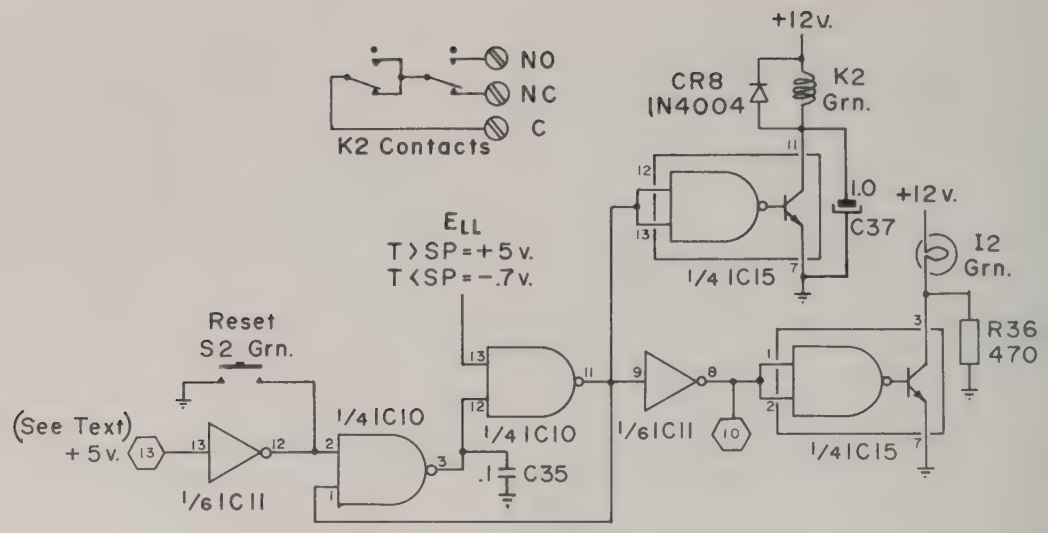
Now, assume that the temperature returns to within limits. This means that pin 10 of IC10 will return to the high state. However, pin 9 of IC10 is still low, so pin 8 of IC10 will stay high. From this we can see that the High Limit alarm circuit has a latching feature, and will not reset automatically.

This circuit may be manually reset by depressing the lighted push button switch S1. This momentarily causes pin 5 of IC10 to go low, forcing pin 6 of IC10 to swing high, which reestablishes the initial normal mode of operation.

The above detailed analysis of the *High Limit logic circuitry* has been provided so as to illustrate how easy it



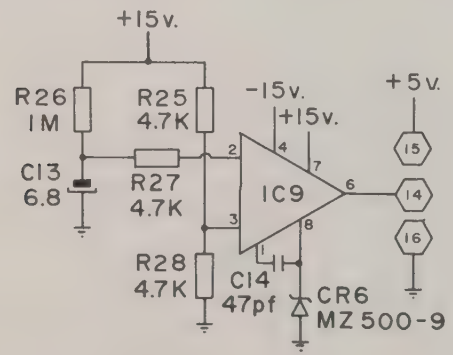
470095 HIGH LIMIT ALARM CKT.



470096 LOW LIMIT ALARM CKT.

is to tell what's happening in digital circuitry. As is evident from the above, one's only problem will be keeping track of which pins are high and which pins are low, as he traces through the loops.

It was indicated above that terminal 13 is normally low. Terminal 13 is normally connected to terminal 14 at pin 6 of IC9. This (IC9, etc.) is the *auto-restart circuit.* When power is applied to the Productsaver, this circuit will automatically reset the alarm circuits during the first 15 seconds of operation.



470099 AUTO RESTART CKT.

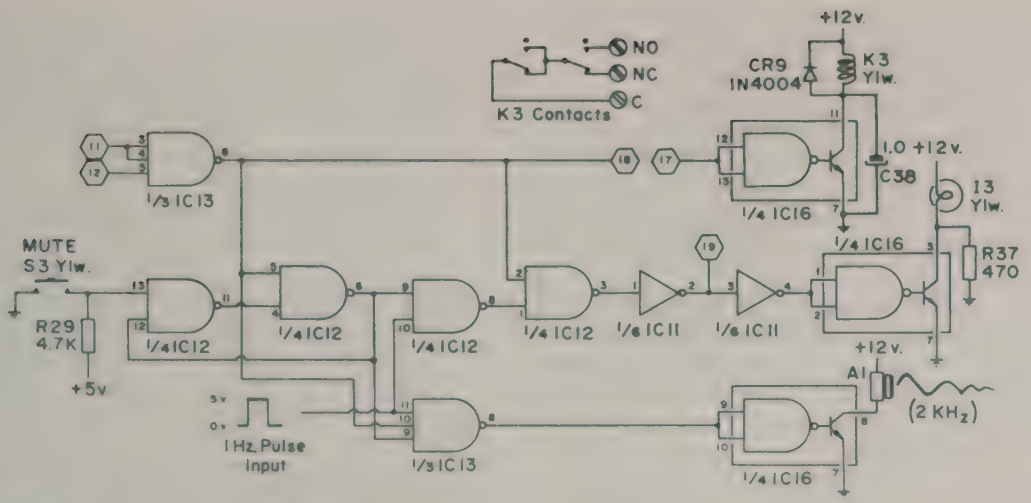
R25 and R28 form a voltage divider which establishes pin 3 of IC9 at +7.5vdc. When power is first applied, C13 will begin to charge towards the +15vdc supply voltage, but at this first instant the voltage seen at pin 2 of IC9 will be about −15vdc, since the capacitor looks like a very low resistance, forming a voltage divider with R26, a very high resistance. At this time, the output of the circuit (at terminal 14) will be clamped at +5.1vdc by CR6.

This means that terminal 13 will be high, and that the outputs of IC11/11-10 and IC11/13-12 will be low, which has the same effect as holding down the two reset switches, S1 and S2.

In time (about 15 seconds) C13 will charge past the +7.5vdc level, and as it does so the output of IC9 will switch from +5.1vdc to about −0.7vdc, again being clamped at this level by the forward characteristics of CR6. This condition will be sustained until power is again interrupted. Hence, terminal 13 'is normally low.'

When power is interrupted, C13 discharges and this circuit is readied for another start up cycle. R27 is used to protect the inverting input of IC9, since C13 may not discharge completely prior to the time that the supplies drop to zero. C14 is the compensation capacitor for IC9. By connecting terminal 13 to terminal 15, the user can provide continuous automatic reset. By connecting terminal 13 to terminal 16, manual reset without the auto restart feature is provided. With this latter connection, *power failure detection* is also achieved since upon start up both the High Limit and Low Limit alarm circuits will be activated. This results from the fact that pins 10 and 13 of IC10 are low upon start up.

It will be noticed that the *Low Limit logic,* which drives K2 and I2, is identical to the High Limit logic. Detailed analysis of this circuit is left as a review exercise for the reader. Capacitors C34 and C35 are used to slow



470097 HIGH–LOW LIMIT ALARM CIRCUIT

the response of these circuits somewhat so that stray noise signals can not inadvertantly reset them after they have latched in the alarm mode.

Terminals 11 and 12 constitute the inputs to the *Hi/Lo Limit logic* circuitry. As indicated on the schematic diagram, these terminals are normally connected to terminals 9 and 10, respectively. With these connections the Hi/Lo Limit alarm circuit is reset manually with the High Limit and Low Limit circuits. Automatic reset for the Hi/Lo Limit circuit only can be achieved by connecting terminals 11 and 12 to terminals 7 and 8, respectively.

During normal operation the following conditions will prevail

Relay K3 : energised
lamp I3 : off
audible alarm A1: off

If the high or low limit is exceeded

relay K3 : deenergised
lamp I3 : flashing on/off/on . . .
audible alarm A1 : pulsing on/off/on . . .

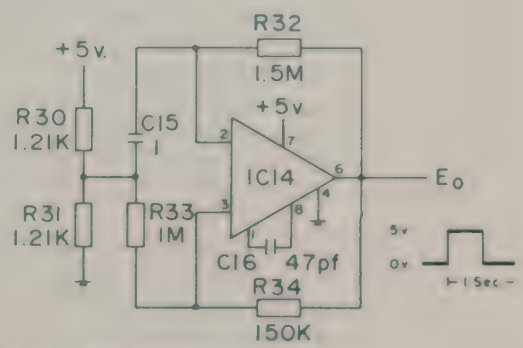
And, when mute switch S3 is depressed

relay K3 : deenergised
lamp I3 : on
audible alarm A1 : off

Proving the above is left as an exercise for the reader. As a user option, terminal 17 may be connected to terminal 19, which causes K3 to be energised when lamp I3 is off, meaning that K3 will pulse on and off with the lamp and audible alarm during alarm conditions, until S3 is depressed. Such operation is sometimes desireable when K3 is used to operate a remote warning device. R29 is included to assure that pin 13 of IC12 remains high when S3 is open.

The circuit composed of IC14 and its associated components is a free running multivibrator which is used to provide the signal which flashes the Hi/Lo Limit indicator and audible alarm. Bilateral power for this circuit is simulated using +5.0vdc as the plus potential, ground as the minus potential, and a level of +2.5vdc as the 'common' connection.

The 2.5vdc potential is provided by the voltage divider network R30 and R31. C16 is the compensation capacitor.



470098 PULSE GENERATOR

To analyze this circuit we will assume that its output, pin 6 of IC14, has just switched to +4.8vdc, the approximate positive saturation voltage. A small current will flow from the +2.5vdc common connection to the +4.8vdc potential at pin 6 of IC14 (about 2.1μA), thru R33 and

R34. This will produce a voltage drop of about 315mV across R34. Hence the voltage applied to pin 3 of IC14 will be about (+4.8vdc −315mV) +4.5vdc.

In the meantime C15 is charging towards the positive potential at pin 6, at a rate determined by its size times the value of R32. When the voltage across C15, which is also applied to the inverting input of IC14, pin 2, reaches the value applied to pin 3 . . . about +4.5vdc . . . the output at pin 6 will switch to its negative saturation value, about +0.2vdc.

Now the operation of the circuit reverses itself. The voltage at pin 3 changes to about +0.5vdc and capacitor C15 charges towards the negative saturation value at pin 6. When the voltage across C15 reaches +0.5vdc, the circuit switches back to the previous state, with pin 6 rising to a potential of about +4.8vdc, once again.

This flip-flop action continues indefinitely with a frequency of approximately 1.0Hz. Since this signal is used to operate the Hi/Lo Limit indicator and audible alarm in their flashing/pulsing modes, they will be operated at this frequency; ½ second on - ½ second off.

The switches S1, S2 and S3 are an integral part of indicators I1, I2 and I3, respectively. To reset or mute the Productsaver, the user need merely depress the lighted indicator without having to read inscriptions, etc.

Diodes CR7, CR8 and CR9 are used to suppress transients produced by relays K1, K2 and K3, respectively. In the absence of these diodes, these inductive devices will produce spikes having an amplitude in excess of 1000 volts when they are switched. Capacitors C36, C37 and C38 prevent oscillation at the relay driver circuits as they switch thru their linear range. Resistors R35, R36 and R37 provide pre-heat current to the lamps of indicators I1, I2 and I3 respectively, in order to limit their inrush current when turned on. Otherwise, the cold filament inrush current for these lamps exceeds 0.5 amperes, which would momentarily overload both the driver transistors and the +12vdc power supply.

As illustrated on the schematic diagram, the output relay contacts are connected in the 'double-break' form, which theoretically improves upon their electrical life by distributing make/break arcing over two air gaps, instead of one, thereby extinguishing such arcs faster and reducing the contact temperature rise. It should be noted that the marking on the terminal circuit board applies to the relays themselves (n. o., n. c., etc.) and not to the manner in which they are operated by the Productsaver circuitry. In normal operation (no alarms) these relays will all be energised. They will be deenergised when an alarm occurs, or when power is removed from the unit.

MAINTENANCE

The Productsaver requires no periodic maintenance, as such. Good maintenance practice suggests that the unit be inspected from time to time for contamination, loose connections, etc. The practical inspection interval will vary with the application and the nature of the environment in which the unit is used.

If necessary, blow accumulations of dust out of the unit using compressed air (30psi max.). In extreme cases all parts of the unit except the meter may be cleaned of accumulated dirt using a mild detergent in warm water, followed by a thorough rinse with demineralized water. Insure that the unit is thoroughly dried out prior to reassembly and return to service.

The desired calibration interval must also be established by the user. In this type of equipment component aging is usually responsible for calibration drift. In the case of the Productsaver however, the use of top quality solid state and passive components minimizes the probability of such variation, and should be considered when establishing calibration varification requirements.

When the Productsaver was designed, the importance of reliability in this type of instrumentation was recognized. For this reason the circuit includes a high level of redundancy. Only top quality component parts are used in its construction, and each part is conservatively rated. If and when failures do occur, troubleshooting is simplified by the fact that most of the individual circuits within the unit consist of an integrated device. These devices typically combine forty to seventy circuit elements into a single replaceable package, leaving only a few discrete components on the outside. Furthermore, each section of the Productsaver circuit usually performs a single, clearly identified function, and it is therefore fairly simple to work thru the entire circuit on a GO/NO−GO basis until the faulty circuit is isolated.

When troubleshooting becomes necessary, there is simply no substitute for knowledge. With this in mind, a comprehensive explanation of the Productsaver circuit is provided in this manual under the heading FUNCTIONAL ANALYSIS. This explanation includes the designed purpose of every electronic component part. Sometimes a visual inspection of the circuitry will locate the fault in short order. Where this is not the case, poking around in unfamiliar circuitry and replacing suspect parts usually wastes a lot of time and a lot of parts. In such cases, it is usually much more expedient to simply sit down for an hour or two and study the circuitry until it is reasonably well understood, prior to doing any actual troubleshooting.

When troubleshooting any electronic circuit, its dc power supplies must always be tested for proper operation as THE FIRST STEP. In the case of the Productsaver, the output of these supplies should be within 1% of their

assigned values, except for the 30vdc unregulated supply, which may vary by ±15%. Other than this, and because of our philosophy, as expressed above, Thermotron has provided no 'troubleshooting guide' as such, in this manual.

SERVICE

Where troubleshooting assistance is required, phone or write Thermotron - ACS Customer Service (see back cover).

Users desiring to return units for service at the factory should contact Thermotron - ACS Customer Service in advance for a returned goods authorization number. Returned units shoud be CAREFULLY PACKED TO PREVENT DAMAGE IN SHIPMENT. Double packing (two cartons, each with excelsior all around the contents) is recommended.

All returns should be accompanied by a purchase order showing the Thermotron returned goods authorization number, return shipment instructions, the nature of the service requirement (what seems to be wrong, with as much detail as possible), and the name of a person at the customer's plant who can be contacted for further information.

All shipping related to service is handled FOB Holland, Michigan. UNITS ARRIVING AT HOLLAND IN AN APPARENTLY DAMAGED CONDITION OR WITHOUT PRIOR AUTHORIZATION CAN NOT BE RECEIVED. All units accepted for service will receive immediate attention at the factory, with 24-hour turn-arounds provided in many cases. Unless otherwise specified on your order, outbound repaired units will be shipped using the same method as the inbound shipment.

Orders for service parts should also be directed to Thermotron - ACS Customer Service. All Productsaver parts are normally stocked at the factory, and in most cases 'same-day' shipment can be provided. In order to expedite service and assure that the correct parts are shipped, all items should be identified by the Thermotron six-digit part number (IISS number), in addition to their noun and spec.

e.g.
052347 RESISTOR, Film 2.4K ¼w 1%

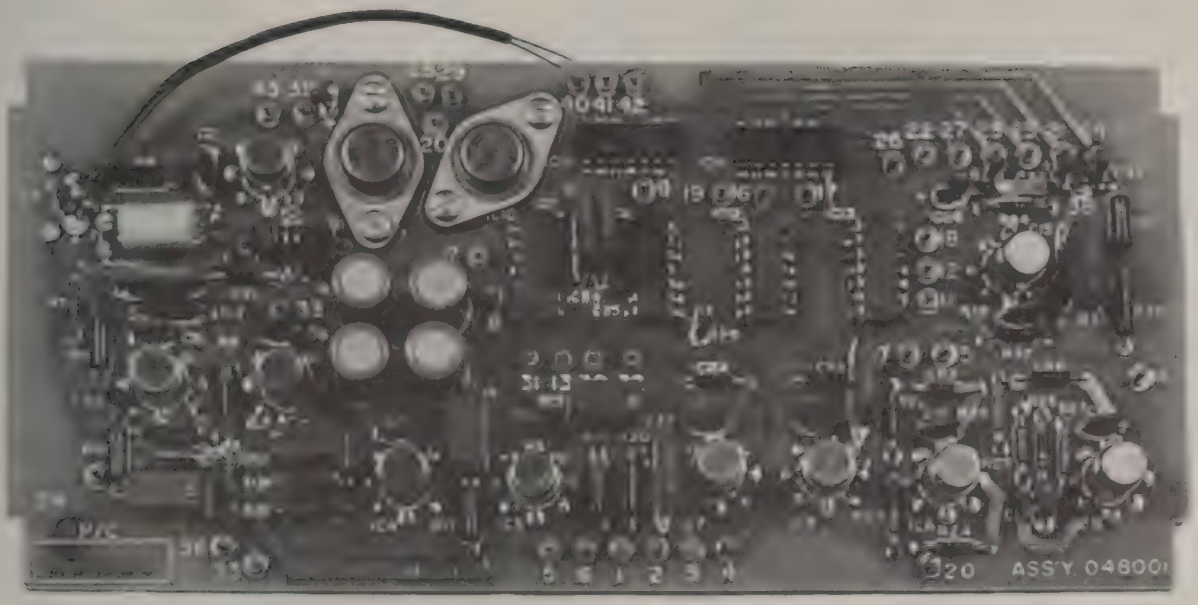
PARTS LIST

Productsaver
Model 012001

IISS	DESCRIPTION	Qty
041002	BRACKET, Mounting	2
048001	†PCB ASSY., Main	1
048002	†PCB ASSY., Power	1
048003	†PCB ASSY., Annunciator	1
048004	†PCB ASSY., Terminal	1
*112003	RELAY, 2P2T 12V	3
123001	METER ASSY., Temp	1
196007	WIRE, Hook-Up 3"	7
196008	WIRE, Hook-Up 4"	3
196009	WIRE, Hook-Up 5"	3
196010	WIRE, Hook-Up 6"	5
196011	WIRE, Hook-Up 7"	4
196012	WIRE, Hook-Up 8"	6
196013	WIRE, Hook-Up 9"	4
196017	WIRE ASSY., Gnd.	1
198003	CABLE TIE	3
205001	PANEL, Annunciator	1
271028	SCREW, Type A No. 6	2
271029	BOLT, Rdn Hd 5/16-18x2"	2
272004	WASHER, Flt No. 6	6
273003	LOCKWASHER, Split No. 6	4
273011	LOCKWASHER, Int 3/8"	3
274003	NUT, Hex No. 6	4
274006	NUT, Knurled 3/8-32	3
274007	NUT, Knurled 1 1/8-24	1
274008	NUT, Hex 5/16-18	2
*275003	CLIP, Relay Retainer	3
276001	RIVET, 1/8 x 1/8	9
276002	RIVET, 5/32 x 1/4	4
351005	CABINET ASSY.	1
352003	CHASSIS	1
353002	BEZEL	1
354001	CLIP, Detent	4
451003	USER'S MANUAL	1

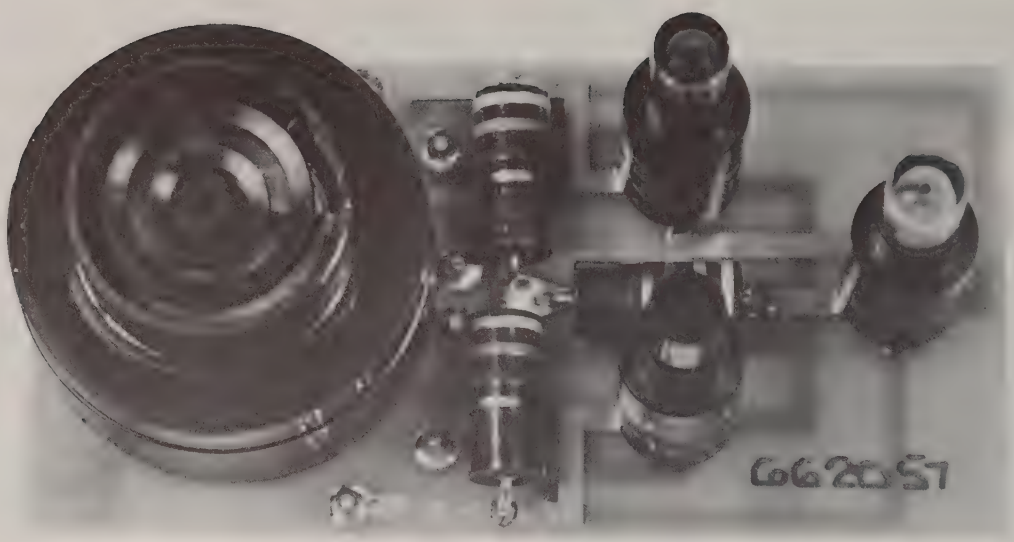
(†) Illustrated parts breakdown provided for these items.

(*) Exact replacement for Sigma relays: order Relay 112001, Retainer Clip 275002.



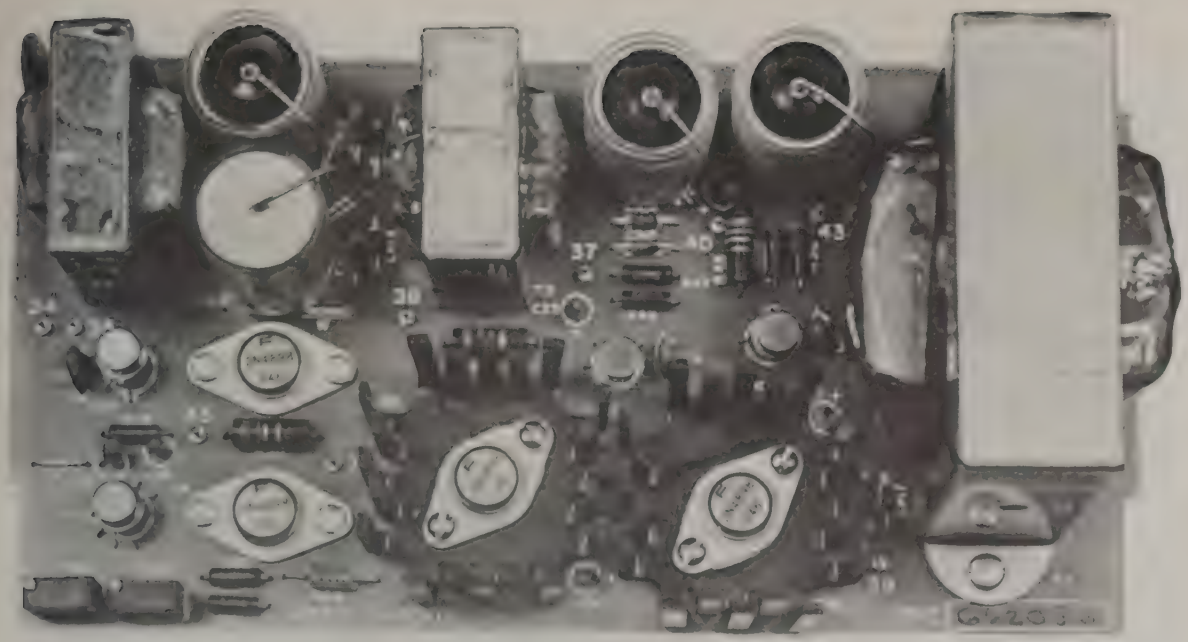
PCB Assy., Main
048001

IISS	DESCRIPTION	Qty
051025	RESISTOR, Comp. 270 Ohms ¼w 5%	1
051036	2.2K	1
051040	4.7K	4
051046	15K	1
051058	150K	1
051068	1 Meg	2
051070	1.5 Meg	1
051082	15 Meg	1
051780	RESISTOR, W.W. 0.68 Ohms 2w 5%	1
052285	RESISTOR, Film 750 Ohms ¼w 1%	1
052309	1.21K	5
052339	2.49K	2
052368	4.99K	1
052414	13.7K	1
052432	21.0K	2
052501	100K	1
052516	143K	1
052578	634K	1
054004	POTENTIOMETER, Trim 5K Ohms 25-T	4
062001	CAPACITOR, Disc 47pf 1000v	8
062003	.1 μf 100v	6
062004	.01 μf 100v	2
063002	CAPACITOR, Tant 1.0 μf 50v	6
063004	6.8 μf 35v	1
063005	15 μf 15v	1
064005	CAPACITOR, Elec 220 μf 6v	4
081001	DIODE, Ref 1N937	2
081007	DIODE, Rect 1N4002	1
081008	DIODE, Zener MZ500-9	3
083003	TRANSISTOR, SP 2N4898	1
083004	TRANSISTOR, SN 2N4910	1
091001	I. C., 4/2in Gate DM946N	2
091002	I. C., Hex Inv DM936N	1
091003	I. C., 3/3in Gate DM962N	1
091004	I. C., 4/2in Pwr Gate UHP-400	2
093001	I. C., Op Amp LM301A	8
093002	I. C., Op Amp LM308A	1
093003	I. C., Pos Reg LM305A	1
169001	RJC ASSY., T-270	1
179001	SOLID PIN, PCB	44
196004	T. C. EXT WIRE, Tx-20 4"	1
201005	PRINTED CIRCUIT BOARD	1
251001	MICA INSULATOR, T0-66	2
271005	SCREW, Bdr Hd 4-40 x 3/8	4
273007	LOCKWASHER, Int No. 4	4
274002	NUT, Hex No. 4	4



PCB Assy., Annunciator
048003

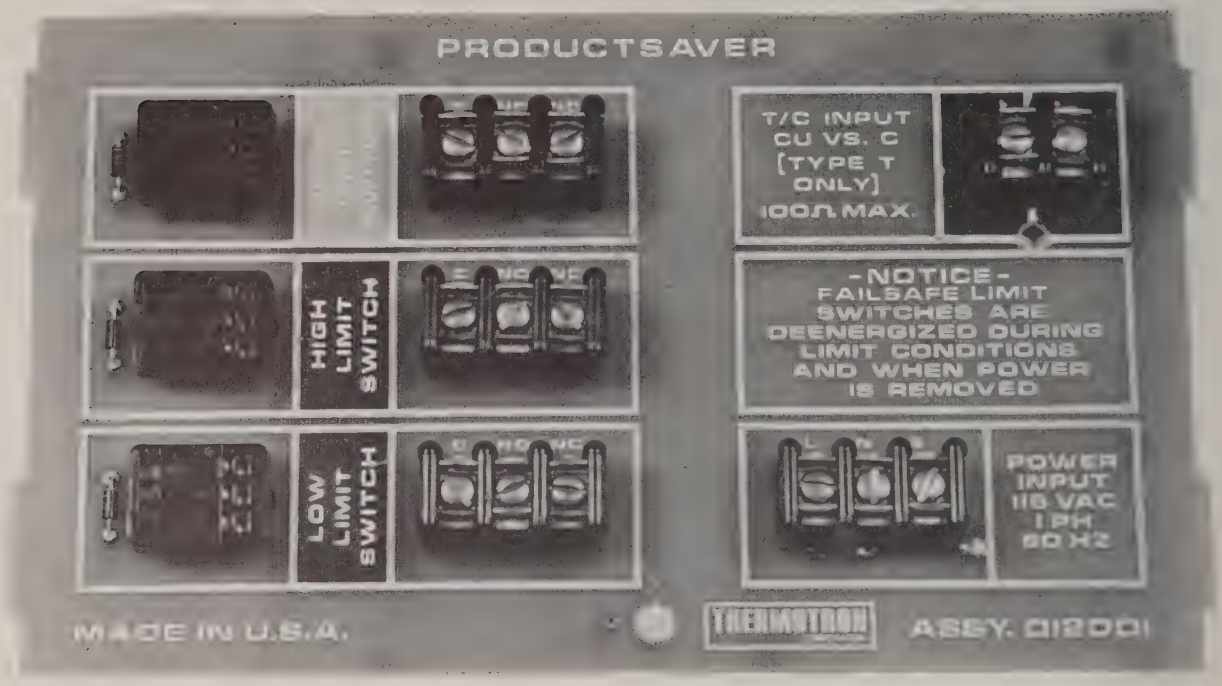
IISS	DESCRIPTION	Qty
051328	RESISTOR, Comp 470 Ohms 2w 5%	3
102001	LITED P. B. SWITCH ASSY., Red	1
102002	LITED P. B. SWITCH ASSY., Grn	1
102003	LITED P. B. SWITCH ASSY., Ylw	1
124001	ANNUNCIATOR ASSY., Audible	1
179001	SOLID PIN, PCB	10
201007	PRINTED CIRCUIT BOARD	1



PCB Assy., Power
048002

IISS	DESCRIPTION		Qty
051780	RESISTOR, W. W.	0.68 Ohms 2w 5%	1
051781		1.8	1
051782		6.8	1
051783		10.0	1
052338	RESISTOR, Film	2.43K Ohms ¼w 1%	2
052344		2.8K	1
052372		5.49K	1
052381		6.81K	1
052401		10.0K	1
052417		14.7K	1
054004	POTENTIOMETER,	Trim 5K Ohms 25-T	2
062001	CAPACITOR, Disc	47pf 1000v	3
062002		.01 µf 1400v	1
063002	CAPACITOR, Tant	1.0 µf 50v	4
063003		4.7 µf 50v	2
064002	CAPACITOR, Elec	250 µf 50v	4
071003	TRANSFORMER, Pwr	115v/42vct	1
071004		115v/30vct	1
071005		115v/17vct	1

081007	DIODE, Rect 1N4002		8
083003	TRANSISTOR, SP 2N4898		4
093003	I. C., Pos Reg	LM305A	3
093004	I. C., Neg Reg	LM304	1
179001	SOLID PIN, PCB		13
199007	WIRE, Jumper 0.4"		2
201006	PRINTED CIRCUIT BOARD		1
233002	HEAT SINK, TO-66		2
271005	SCREW, Bdr Hd 4-40 x 3/8		4
271014	SCREW, Bdr Hd 6-32 x 3/8		2
271030	SCREW, Fil Hd 6-32 x 3/8		4
272004	WASHER, Flt No. 6		4
273003	LOCKWASHER, Split No. 6		2
273007	LOCKWASHER, Int No. 4		4
273008	LOCKWASHER, Int No. 6		4
274002	NUT, Hex No. 4		4
274003	NUT, Hex No. 6		6



PCB Assy., Terminal
048004

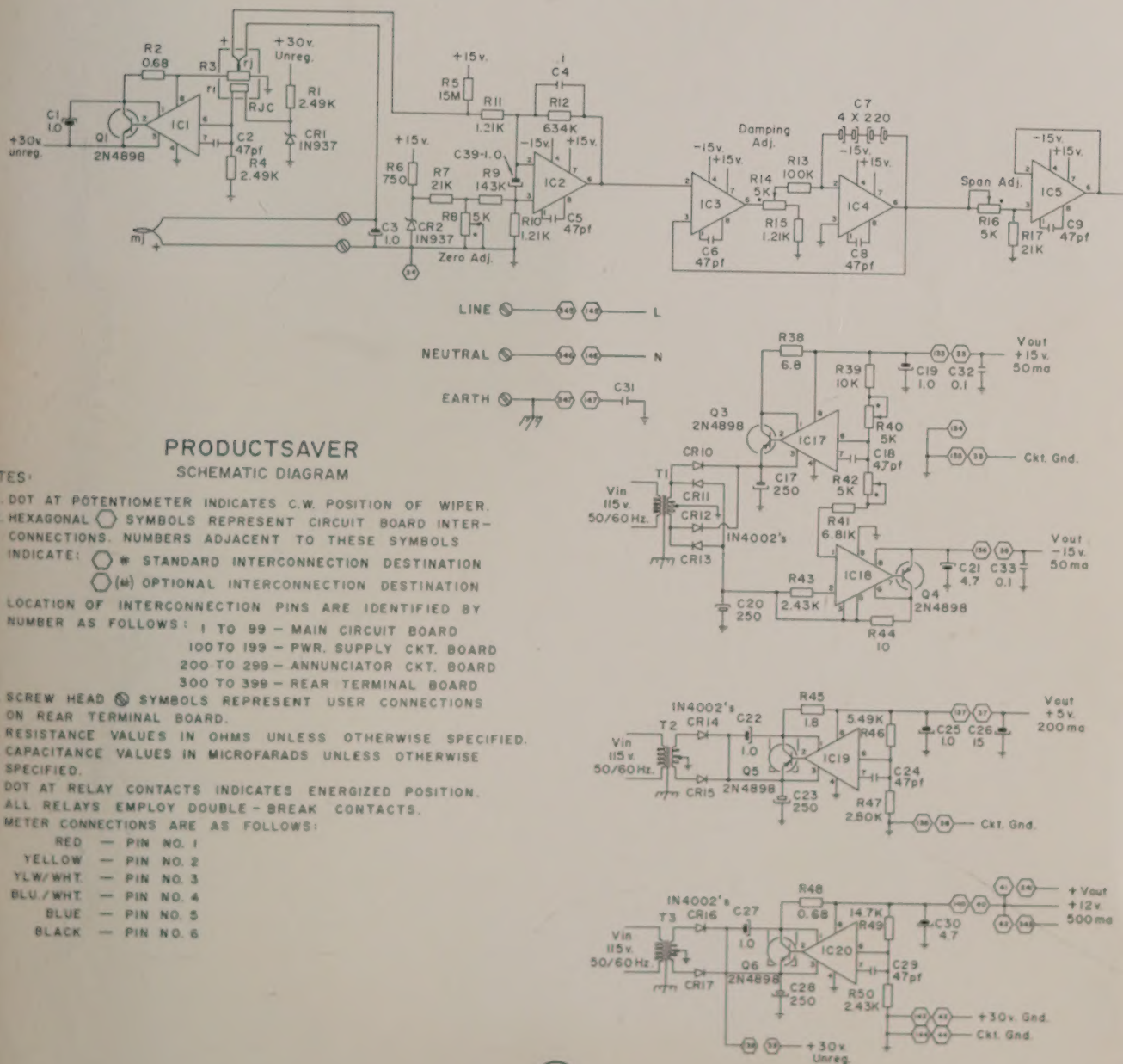
IISS	DESCRIPTION	Qty
081004	DIODE, Rect 1N4004	3
175001	SOCKET, Relay 2P2T	3
176003	TERMINAL BLOCK, 3-way	4
176004	TERMINAL BLOCK, 2-way	1
179001	SOLID PIN, PCB	8
201008	PRINTED CIRCUIT BOARD	1

PARTS LIST, Symbolic

Productsaver
Model 012001

Sym	Type	Desc	IISS	Loc
A1		Wistle	124001	A
C1	tant	1.0 µf	063002	M
C2	disc	47pf	062001	M
C3	tant	1.0 µf	063002	M
C4	disc	.1 µf	062003	M
C5	disc	47pf	062001	M
C6	disc	47pf	062001	M
C7	elec	4 x 220 µf	064005	M
C8	disc	47pf	062001	M
C9	disc	47pf	062001	M
C10	disc	47pf	062001	M
C11	disc	.01 µf	062004	M
C12	disc	.01 µf	062004	M
C13	tant	6.8 µf	063004	M
C14	disc	47pf	062001	M
C15	disc	.1 µf	062003	M
C16	disc	47pf	062001	M
C17	elec	250 µf	064002	P
C18	disc	47pf	062001	P
C19	tant	1.0 µf	063002	P
C20	elec	250 µf	064002	P
C21	tant	4.7 µf	063003	P
C22	tant	1.0 µf	063002	P
C23	elec	250 µf	064002	P
C24	disc	47pf	062001	P
C25	tant	1.0 µf	063002	P
C26	tant	15 µf	063005	M
C27	tant	1.0 µf	063002	P
C28	elec	250 µf	064002	P
C29	disc	47pf	062001	P
C30	tant	4.7 µf	063003	P
C31	disc	.01 µf	062002	P
C32	disc	1 µf	062003	M
C33	disc	1 µf	062003	M
C34	disc	1 µf	062003	M
C35	disc	1 µf	062003	M
C36	tant	1.0 µf	063002	M
C37	tant	1.0 µf	063002	M
C38	tant	1.0 µf	063002	M
C39	tant	1.0 µf	063002	M
CR1	ref	1N937	081001	M
CR2	ref	1N937	081001	M
CR3	rect	1N4002	081007	M
CR4	zen	MZ500-9	081008	M
CR5	zen	MZ500-9	081008	M
CR6	zen	MZ500-9	081008	M
CR7	rect	1N4004	081004	T
CR8	rect	1N4004	081004	T
CR9	rect	1N4004	081004	T
CR10	rect	1N4002	081007	P
CR11	rect	1N4002	081007	P
CR12	rect	1N4002	081007	P
CR13	rect	1N4002	081007	P
CR14	rect	1N4002	081007	P
CR15	rect	1N4002	081007	P
CR16	rect	1N4002	081007	P
CR17	rect	1N4002	081007	P
I/S1	lpbs	red	102001	A
I/S2	lpbs	grn	102002	A
I/S3	lpbs	ylw	102003	A
K1	2p2t	12v	112003	T
K2	2p2t	12v	112003	T
K3	2p2t	12v	112003	T
IC1	pvr	LM305A	093003	M
IC2	oa	LM308A	093002	M
IC3	oa	LM301A	093001	M
IC4	oa	LM301A	093001	M
IC5	oa	LM301A	093001	M
IC6	oa	LM301A	093001	M
IC7	oa	LM301A	093001	M
IC8	oa	LM301A	093001	M
IC9	oa	LM301A	093001	M
IC10	4ng	DM946N	091001	M
IC11	hxi	DM936N	091002	M
IC12	4ng	DM946N	091001	M
IC13	3ng	DM962N	091003	M
IC14	oa	LM301A	093001	M
IC15	4npg	UHP400	091004	M
IC16	4npg	UHP400	091004	M
IC17	pvr	LM305A	093003	P
IC18	nvr	LM304	093004	P
IC19	pvr	LM305A	093003	P
IC20	pvr	LM305A	093003	P

Q1	pnp	2N4898	083003	M
Q2	npn	2N4910	083004	M
Q3	pnp	2N4898	083003	P
Q4	pnp	2N4898	083003	P
Q5	pnp	2N4898	083003	P
Q6	pnp	2N4898	083003	P
R1	film	2.49K	052339	M
R2	ww	0.68	051780	M
R3	spxl	(RJC)	w/169001	M
R4	film	2.49K	052339	M
R5	comp	15Meg	051082	M
R6	film	750	052285	M
R7	film	21K	052432	M
R8	pot	5K	054004	M
R9	film	143K	052516	M
R10	film	1.21K	052309	M
R11	film	1.21K	052309	M
R12	film	634K	052578	M
R13	film	100K	052501	M
R14	pot	5K	054004	M
R15	film	1.21K	052309	M
R16	pot	5K	054004	M
R17	film	21K	052432	M
R18	film	4.99K	052368	M
R19	pot	5K	054004	M
R20	film	13.7K	052414	M
R21	pot	(7.9K)	w/123001	—
R22	comp	270	051025	M
R23	comp	15K	051046	M
R24	comp	2.2K	051036	M
R25	comp	4.7K	051040	M
R26	comp	1 Meg	051068	M
R27	comp	4.7K	051040	M
R28	comp	4.7K	051040	M
R29	comp	4.7K	051040	M
R30	film	1.21K	052309	M
R31	film	1.21K	052309	M
R32	comp	1.5 Meg	051070	M
R33	comp	1 Meg	051068	M
R34	comp	150K	051058	M
R35	comp	470	051328	A
R36	comp	470	051328	A
R37	comp	470	051328	A
R38	ww	6.8	051782	P
R39	film	10K	052401	P
R40	pot	5K	054004	P
R41	film	6.81K	052381	P
R42	pot	5K	054004	P
R43	film	2.43K	052338	P
R44	ww	10	051783	P
R45	ww	1.8	051781	P
R46	film	5.49K	052372	P
R47	film	2.80K	052344	P
R48	ww	0.68	051780	P
R49	film	14.7K	052417	P
R50	film	2.43K	052338	P
RJC		T-270	169001	M
S1	(see I/S1)			
S2	(see I/S2)			
S3	(see I/S3)			
T1	pwr	30vct	071004	P
T2	pwr	17vct	071005	P
T3	pwr	42vct	071003	P

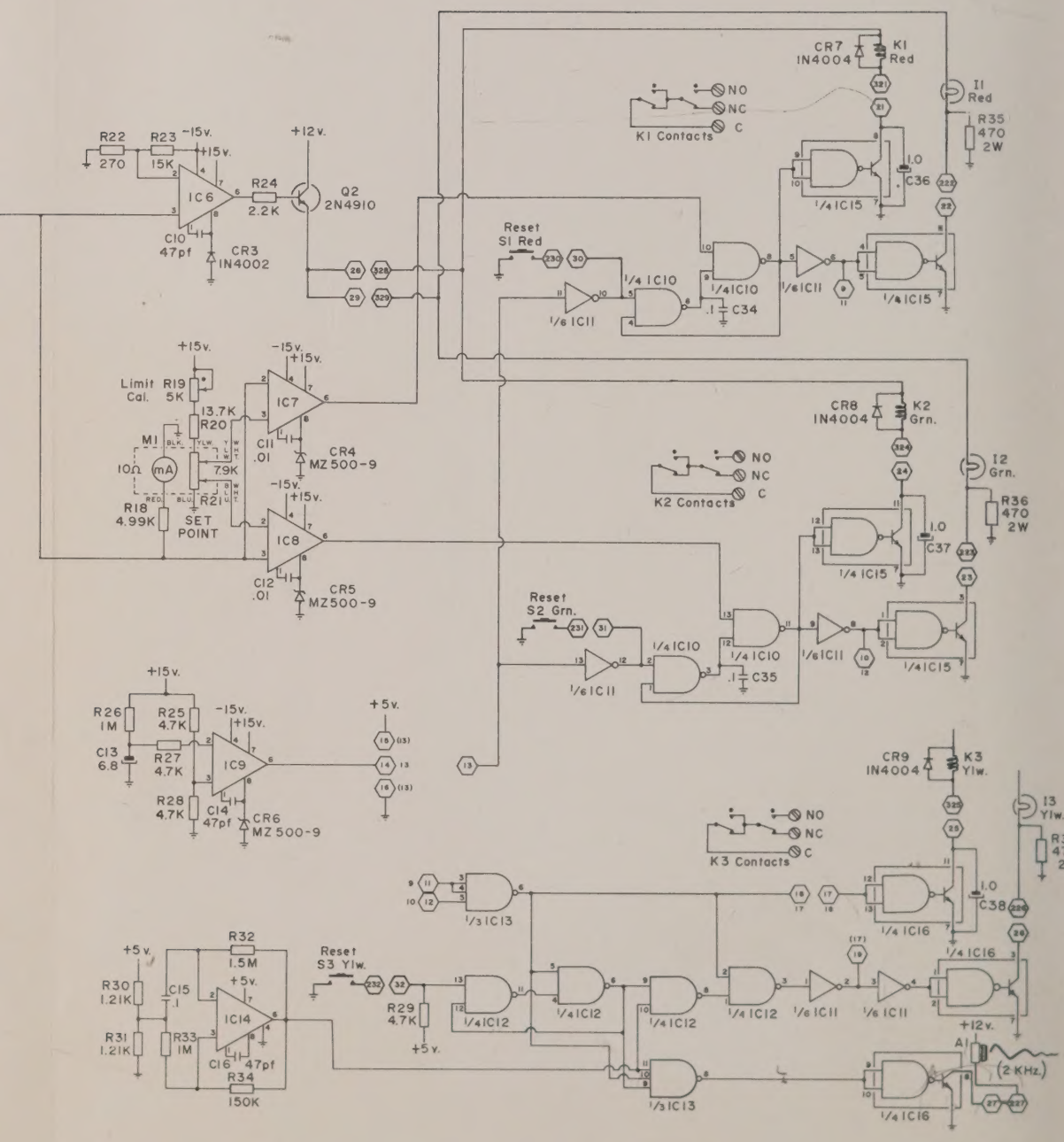


PRODUCTSAVER

SCHEMATIC DIAGRAM

NOTES:

1. DOT AT POTENTIOMETER INDICATES C.W. POSITION OF WIPER.
2. HEXAGONAL ⬡ SYMBOLS REPRESENT CIRCUIT BOARD INTER-CONNECTIONS. NUMBERS ADJACENT TO THESE SYMBOLS INDICATE: ⬡ # STANDARD INTERCONNECTION DESTINATION
   ⬡ (#) OPTIONAL INTERCONNECTION DESTINATION
   LOCATION OF INTERCONNECTION PINS ARE IDENTIFIED BY NUMBER AS FOLLOWS: 1 TO 99 – MAIN CIRCUIT BOARD
   100 TO 199 – PWR. SUPPLY CKT. BOARD
   200 TO 299 – ANNUNCIATOR CKT. BOARD
   300 TO 399 – REAR TERMINAL BOARD
3. SCREW HEAD ⊗ SYMBOLS REPRESENT USER CONNECTIONS ON REAR TERMINAL BOARD.
4. RESISTANCE VALUES IN OHMS UNLESS OTHERWISE SPECIFIED.
5. CAPACITANCE VALUES IN MICROFARADS UNLESS OTHERWISE SPECIFIED.
6. DOT AT RELAY CONTACTS INDICATES ENERGIZED POSITION. ALL RELAYS EMPLOY DOUBLE-BREAK CONTACTS.
7. METER CONNECTIONS ARE AS FOLLOWS:
   RED — PIN NO. 1
   YELLOW — PIN NO. 2
   YLW/WHT. — PIN NO. 3
   BLU./WHT. — PIN NO. 4
   BLUE — PIN NO. 5
   BLACK — PIN NO. 6


SCHEMATIC DIAGRAM
R22 270
R23 15K
-15v.
+15v.
IC6
R24 2.2K
+12v.
Q2 2N4910
C10 47pf
CR3 IN4002
CR7 IN4004
K1 Red
K1 Contacts
NO
NC
C
I1 Red
R35 470 2W
1.0 C36
1/4 IC15
Reset S1 Red
1/4 IC10
1/6 IC11
.1 C34
Limit Cal.
R19 5K
13.7K R20
7.9K R21
SET POINT
M1
10Ω
mA
R18 4.99K
IC7
C11 .01
CR4 MZ500-9
IC8
C12 .01
CR5 MZ500-9
CR8 IN4004
K2 Grn.
K2 Contacts
I2 Grn.
R36 470 2W
Reset S2 Grn.
.1 C35
R26 1M
R25 4.7K
R27 4.7K
R28 4.7K
C13 6.8
IC9
C14 47pf
CR6 MZ500-9
CR9 IN4004
K3 Ylw.
K3 Contacts
I3 Ylw.
R37 470 2W
1.0 C38
1/3 IC13
1/4 IC16
R32 1.5M
R30 1.21K
R31 1.21K
R33 1M
R34 150K
C15 .1
C16 47pf
IC14
Reset S3 Ylw.
R29 4.7K
1/4 IC12
1/3 IC13
A1
(2 KHz.)

COPPER vs. COPPER-NICKEL

(Copper-Constantan)

TYPE T

Temperature in Degrees F

Reference Junction at 32°F

THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS

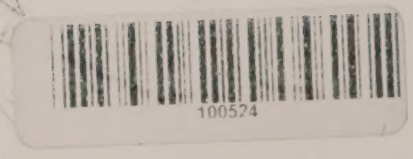
DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F
-190	-4.009	-4.023	-4.037	-4.051	-4.065	-4.079	-4.093	-4.107	-4.121	-4.135	-4.149	-190
-180	-3.864	-3.879	-3.894	-3.908	-3.923	-3.937	-3.951	-3.966	-3.980	-3.994	-4.009	-180
-170	-3.717	-3.732	-3.746	-3.761	-3.776	-3.791	-3.806	-3.820	-3.835	-3.850	-3.864	-170
-160	-3.565	-3.580	-3.596	-3.611	-3.626	-3.641	-3.656	-3.671	-3.687	-3.702	-3.717	-160
-150	-3.410	-3.425	-3.441	-3.457	-3.472	-3.488	-3.503	-3.519	-3.534	-3.550	-3.565	-150
-140	-3.251	-3.267	-3.283	-3.299	-3.315	-3.331	-3.347	-3.362	-3.378	-3.394	-3.410	-140
-130	-3.089	-3.105	-3.121	-3.138	-3.154	-3.170	-3.186	-3.203	-3.219	-3.235	-3.251	-130
-120	-2.923	-2.939	-2.956	-2.973	-2.989	-3.006	-3.023	-3.039	-3.056	-3.072	-3.089	-120
-110	-2.753	-2.771	-2.788	-2.805	-2.822	-2.838	-2.855	-2.872	-2.889	-2.906	-2.923	-110
-100	-2.581	-2.598	-2.616	-2.633	-2.650	-2.667	-2.685	-2.702	-2.719	-2.736	-2.753	-100
-90	-2.405	-2.422	-2.440	-2.458	-2.475	-2.493	-2.511	-2.528	-2.546	-2.563	-2.581	-90
-80	-2.225	-2.243	-2.261	-2.279	-2.297	-2.315	-2.333	-2.351	-2.369	-2.387	-2.405	-80
-70	-2.042	-2.061	-2.079	-2.098	-2.116	-2.134	-2.152	-2.171	-2.189	-2.207	-2.225	-70
-60	-1.856	-1.875	-1.894	-1.912	-1.931	-1.950	-1.968	-1.987	-2.005	-2.024	-2.042	-60
-50	-1.667	-1.686	-1.705	-1.724	-1.743	-1.762	-1.781	-1.800	-1.819	-1.838	-1.856	-50
-40	-1.475	-1.494	-1.513	-1.533	-1.552	-1.571	-1.591	-1.610	-1.629	-1.648	-1.667	-40
-30	-1.279	-1.299	-1.319	-1.338	-1.358	-1.377	-1.397	-1.416	-1.436	-1.455	-1.475	-30
-20	-1.081	-1.101	-1.121	-1.141.	-1.160	-1.180	-1.200	-1.220	-1.240	-1.260	-1.279	-20
-10	-0.879	-0.899	-0.920	-0.940	-0.960	-0.980	-1.000	-1.021	-1.041	-1.061	-1.081	-10
0	-0.674	-0.695	-0.716	-0.736	-0.757	-0.777	-0.798	-0.818	-0.838	-0.859	-0.879	0
DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F
0	-0.674	-0.654	-0.633	-0.613	-0.592	-0.571	-0.550	-0.529	-0.509	-0.488	-0.467	0
10	-0.467	-0.446	-0.425	-0.404	-0.383	-0.362	-0.341	-0.320	-0.299	-0.277	-0.256	10
20	-0.256	-0.235	-0.214	-0.193	-0.171	-0.150	-0.129	-0.107	-0.086	-0.064	-0.043	20
30	-0.043	-0.022	0.000	0.022	0.043	0.065	0.086	0.108	0.130	0.151	0.173	30
40	0.173	0.195	0.216	0.238	0.260	0.282	0.303	0.325	0.347	0.369	0.391	40
50	0.391	0.413	0.435	0.457	0.479	0.501	0.523	0.545	0.567	0.589	0.611	50
60	0.611	0.634	0.656	0.678	0.700	0.722	0.745	0.767	0.789	0.812	0.834	60
70	0.834	0.857	0.879	0.902	0.924	0.947	0.969	0.992	1.014	1.037	1.060	70
80	1.060	1.082	1.105	1.128	1.151	1.173	1.196	1.219	1.242	1.265	1.288	80
90	1.288	1.311	1.334	1.357	1.380	1.403	1.426	1.449	1.472	1.495	1.518	90
100	1.518	1.542	1.565	1.588	1.611	1.635	1.658	1.681	1.705	1.728	1.752	100
110	1.752	1.775	1.799	1.822	1.846	1.869	1.893	1.917	1.940	1.964	1.988	110
120	1.988	2.011	2.035	2.059	2.083	2.107	2.131	2.154	2.178	2.202	2.226	120
130	2.226	2.250	2.274	2.298	2.322	2.347	2.371	2.395	2.419	2.443	2.467	130
140	2.467	2.492	2.516	2.540	2.565	2.589	2.613	2.638	2.662	2.687	2.711	140
150	2.711	2.736	2.760	2.785	2.809	2.834	2.859	2.883	2.908	2.933	2.958	150
160	2.958	2.982	3.007	3.032	3.057	3.082	3.107	3.131	3.156	3.181	3.206	160
170	3.206	3.231	3.256	3.281	3.307	3.332	3.357	3.382	3.407	3.432	3.458	170
180	3.458	3.483	3.508	3.533	3.559	3.584	3.609	3.635	3.660	3.686	3.711	180
190	3.711	3.737	3.762	3.788	3.813	3.839	3.864	3.890	3.916	3.941	3.967	190
200	3.967	3.993	4.019	4.044	4.070	4.096	4.122	4.148	4.174	4.199	4.225	200
210	4.225	4.251	4.277	4.303	4.329	4.355	4.381	4.408	4.434	4.460	4.486	210
220	4.486	4.512	4.538	4.565	4.591	4.617	4.643	4.670	4.696	4.722	4.749	220
230	4.749	4.775	4.801	4.828	4.854	4.881	4.907	4.934	4.960	4.987	5.014	230
240	5.014	5.040	5.067	5.093	5.120	5.147	5.174	5.200	5.227	5.254	5.281	240
250	5.281	5.307	5.334	5.361	5.388	5.415	5.442	5.469	5.496	5.523	5.550	250
260	5.550	5.577	5.604	5.631	5.658	5.685	5.712	5.739	5.767	5.794	5.821	260
270	5.821	5.848	5.875	5.903	5.930	5.957	5.985	6.012	6.039	6.067	6.094	270
280	6.094	6.122	6.149	6.177	6.204	6.232	6.259	6.287	6.314	6.342	6.369	280
290	6.369	6.397	6.425	6.452	6.480	6.508	6.536	6.563	6.591	6.619	6.647	290
300	6.647	6.675	6.702	6.730	6.758	6.786	6.814	6.842	6.870	6.898	6.926	300
310	6.926	6.954	6.982	7.010	7.038	7.066	7.094	7.122	7.151	7.179	7.207	310
320	7.207	7.235	7.263	7.292	7.320	7.348	7.377	7.405	7.433	7.462	7.490	320
330	7.490	7.518	7.547	7.575	7.604	7.632	7.661	7.689	7.718	7.746	7.775	330
340	7.775	7.804	7.832	7.861	7.889	7.918	7.947	7.975	8.004	8.033	8.062	340
350	8.062	8.090	8.119	8.148	8.177	8.206	8.235	8.264	8.292	8.321	8.350	350
360	8.350	8.379	8.408	8.437	8.466	8.495	8.524	8.553	8.583	8.612	8.641	360
370	8.641	8.670	8.699	8.728	8.757	8.787	8.816	8.845	8.874	8.904	8.933	370
380	8.933	8.962	8.992	9.021	9.050	9.080	9.109	9.139	9.168	9.198	9.227	380
390	9.227	9.257	9.286	9.316	9.345	9.375	9.404	9.434	9.464	9.493	9.523	390
400	9.523	9.553	9.582	9.612	9.642	9.671	9.701	9.731	9.761	9.791	9.820	400
410	9.820	9.850	9.880	9.910	9.940	9.970	10.000	10.030	10.060	10.090	10.120	410
420	10.120	10.150	10.180	10.210	10.240	10.270	10.300	10.330	10.360	10.390	10.420	420
430	10.420	10.451	10.481	10.511	10.541	10.572	10.602	10.632	10.662	10.693	10.723	430
440	10.723	10.753	10.784	10.814	10.845	10.875	10.905	10.936	10.966	10.997	11.027	440
450	11.027	11.058	11.088	11.119	11.149	11.180	11.211	11.241	11.272	11.302	11.333	450
460	11.333	11.364	11.394	11.425	11.456	11.487	11.517	11.548	11.579	11.610	11.640	460
470	11.640	11.671	11.702	11.733	11.764	11.795	11.826	11.856	11.887	11.918	11.949	470
480	11.949	11.980	12.011	12.042	12.073	12.104	12.135	12.166	12.198	12.229	12.260	480
490	12.260	12.291	12.322	12.353	12.384	12.416	12.447	12.478	12.509	12.540	12.572	490
500	12.572	12.603	12.634	12.666	12.697	12.728	12.760	12.791	12.822	12.854	12.885	500
510	12.885	12.917	12.948	12.979	13.011	13.042	13.074	13.105	13.137	13.168	13.200	510
520	13.200	13.232	13.263	13.295	13.326	13.358	13.390	13.421	13.453	13.485	13.516	520
530	13.516	13.548	13.580	13.611	13.643	13.675	13.707	13.739	13.770	13.802	13.834	530
540	13.834	13.866	13.898	13.930	13.961	13.993	14.025	14.057	14.089	14.121	14.153	540
550	14.153	14.185	14.217	14.249	14.281	14.313	14.345	14.377	14.409	14.441	14.474	550
560	14.474	14.506	14.538	14.570	14.602	14.634	14.666	14.699	14.731	14.763	14.795	560
570	14.795	14.828	14.860	14.892	14.924	14.957	14.989	15.021	15.054	15.086	15.118	570
580	15.118	15.151	15.183	15.216	15.248	15.280	15.313	15.345	15.378	15.410	15.443	580
590	15.443	15.475	15.508	15.540	15.573	15.605	15.638	15.671	15.703	15.736	15.769	590
600	15.769	15.801	15.834	15.866	15.899	15.932	15.965	15.997	16.030	16.063	16.096	600
610	16.096	16.128	16.161	16.194	16.227	16.259	16.292	16.325	16.358	16.391	16.424	610
620	16.424	16.457	16.490	16.523	16.555	16.588	16.621	16.654	16.687	16.720	16.753	620
630	16.753	16.786	16.819	16.852	16.886	16.919	16.952	16.985	17.018	17.051	17.084	630
640	17.084	17.117	17.150	17.184	17.217	17.250	17.283	17.316	17.350	17.383	17.416	640
650	17.416	17.450	17.483	17.516	17.549	17.583	17.616	17.649	17.683	17.716	17.750	650
660	17.750	17.783	17.816	17.850	17.883	17.917	17.950	17.984	18.017	18.051	18.084	660
670	18.084	18.118	18.151	18.185	18.218	18.252	18.285	18.319	18.353	18.386	18.420	670
680	18.420	18.454	18.487	18.521	18.555	18.588	18.622	18.656	18.689	18.723	18.757	680
690	18.757	18.791	18.824	18.858	18.892	18.926	18.960	18.993	19.027	19.061	19.095	690
700	19.095	19.129	19.163	19.197	19.230	19.264	19.298	19.332	19.366	19.400	19.434	700
710	19.434	19.468	19.502	19.536	19.570	19.604	19.638	19.672	19.706	19.740	19.774	710
720	19.774	19.808	19.843	19.877	19.911	19.945	19.979	20.013	20.047	20.081	20.116	720
730	20.116	20.150	20.184	20.218	20.252	20.287	20.321	20.355	20.389	20.423	20.458	730
740	20.458	20.492	20.526	20.560	20.595	20.629	20.663	20.698	20.732	20.766	20.801	740
750	20.801	20.835	20.869									750

DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F

* CONVERTED FROM DEGREES C (IPTS 1948).

TYPE T

NEW REFERENCE TABLES
SUPERSEDES N.B.S. CIRCULAR #561



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